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THESIS

AN ANALYSIS OF THE LONGBOW HELLFIRE HARDWARE IN THE LOOP LOT ACCEPTANCE PLAN

by

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September 1994

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The Longbow HELLFIRE Hardware in the Loop Lot Acceptance Plan is one of the first attempts by the U.S. Army to defray the costs associated with formal lot acceptance testing by utilizing a non-destructive Hardware in the Loop computer simulation. Because this type of lot acceptance testing is relatively new to the Army, determining the best approach and methodology to use will be critical not only to Longbow HELLFIRE, but to all follow-on systems that could potentially utilize this form of testing in the future. This thesis analyzes the structure, nature and assumptions that were used to develop this Hardware in the Loop plan to determine the essential parts of this form of testing and the problems and issues that are associated with implementing this type of plan.

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An Analysis of the Longbow
HELLFIRE Hardware in the Loop
Lot Acceptance Plan

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Submitted in partial fulfillment
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ABSTRACT

The Longbow HELLFIRE Hardware in the Loop Lot Acceptance Plan is one of the first attempts by the U.S. Army to defray the costs associated with formal lot acceptance testing by utilizing a non-destructive Hardware in the Loop computer simulation. Because this type of lot acceptance testing is relatively new to the Army, determining the best approach [illegible] methodology to use will be critical not only to Longbow HELLFIRE, but to all follow-on systems that could potentially utilize this form of testing in the future. This thesis analyzes the structure, nature and assumptions that were used to develop this Hardware in the Loop plan to determine the essential parts of this form of testing and the problems and issues that are associated with implementing this type of plan.

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I INTRODUCTION

A. PREFACE.

A primary goal of this thesis is to analyze the Longbow HELLFIRE system, the Hardware in the Loop simulation methodology and the statistical properties of lot acceptance testing for the Army Material Command (AMC). This methodology will be compared to the existing HELLFIRE II "Fly to Buy" methodology that has been in effect for the last several years.

B. SYSTEM DESCRIPTION.

1. Missile System Description.

The Longbow HELLFIRE Modular Missile System (LBHMMS) is an integral part of the AH-64D helicopter weapon system, which is designed to defeat multiple armored ground targets and several selected air targets, through the process of radar acquisition targeting and ground engagement (see Figure #1). The LBHMMS consists of:

- Longbow HELLFIRE Modular Missile.
- Longbow HELLFIRE Launcher.
- Longbow Missile Container.
- Longbow Training Missile.
- Radome Environmental Cover.

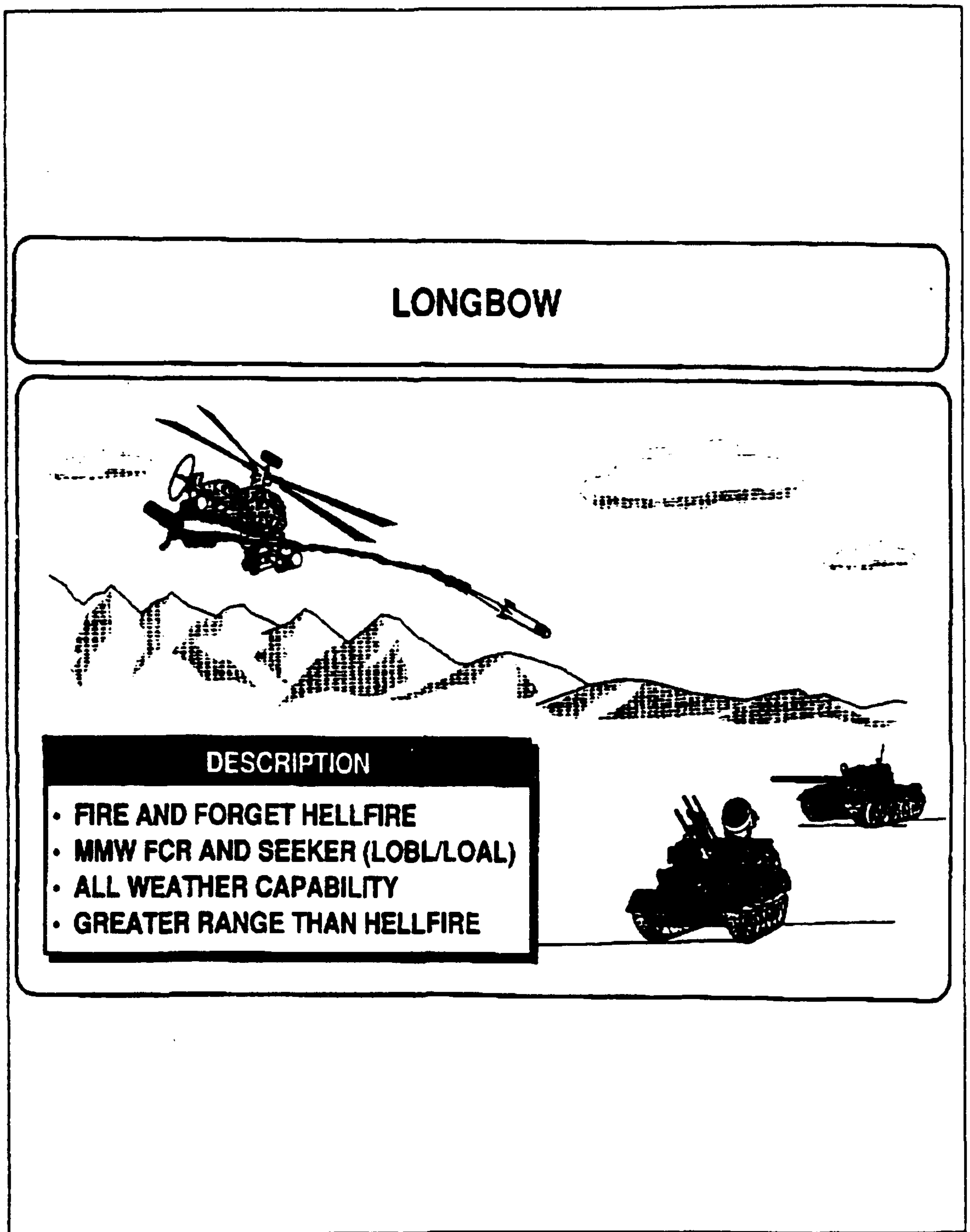

Figure 1 Longbow HELLFIRE System Description

In addition, a missile telemetry sub-system will be designed and used during flight testing of several of the Engineering and Manufacturing Development (EMD) Longbow missiles[1].

Tactical Missile Description. The LBHMMS consists of an active Millimeter Wave (MMW) radar guidance section mated to a HELLFIRE II missile bus. The Longbow missile warhead is a High Explosive Anti-Tank (HEAT) weapon that employs a radar aided inertial guidance system. The bus consists of a warhead section, a propulsion section, and a control section (see Figure #2). The LBHMMS is capable of either a Lock-On-Before-Launch (LOBL) Mode or a Lock-On-After-Launch (LOAL) Mode which describes the two methods in which a target can be engaged by the Longbow Missile. These are the major components and functions that will be referred to through out this thesis.

2. Launch Platforms.

The AH-64D Helicopter is the primary launch platform envisioned for the LBHMMS. The LBHMMS will provide the AH-64D and other airborne launch platforms with a fire-and-forget capability for engaging targets handed over from the Longbow Fire Control Radar (FCR) or its functional equivalent systems, such as the Tactical Air Designation System (TADS), Airborne Target Handoff System (ATHS) and the Integrated Helmet and

[1] For additional information concerning the Longbow HELLFIRE program and points of contact see Appendix A.

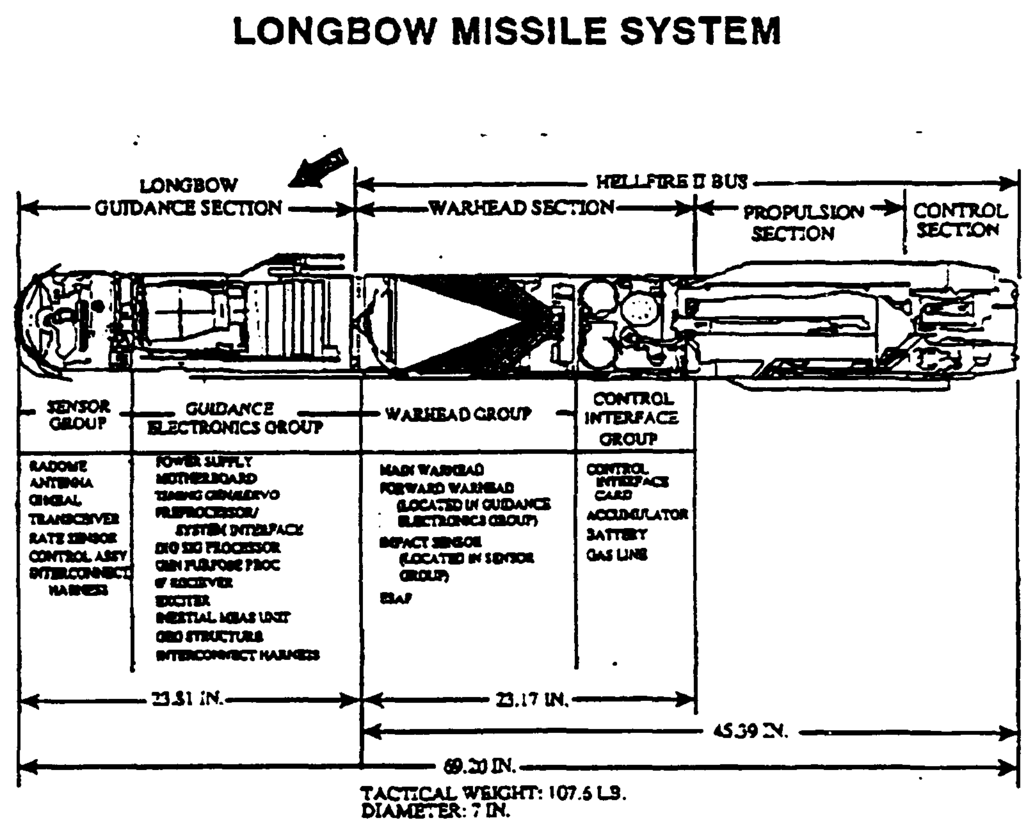

Figure 2 Longbow HELLFIRE Tactical Missile

Display Site System (IHADSS). Future variants may also include a ground launch platform in addition to the airborne platforms described above.

C. BACKGROUND.

For the past several decades, the U.S. Army has required virtually all existing tactical missile systems, be purchased only after a representative sample of missiles from each lot, the production lot, has been successfully tested to confirm specified performance requirements. The purpose of such lot acceptance testing plans is to provide a qualitative assessment of missile system reliability for the entire lot and to provide an accept/reject decision rule for the entire lot of missiles. Under this procedure, the contractor only delivers and gets paid for, those lots that pass this acceptance test.

The "Fly to Buy" acceptance methodology, by its very nature, requires that these sample missile systems be fired in a scenario that represents the actual or anticipated requirement that the missile system would be likely to encounter under actual battlefield conditions. This inevitably results in the missile being destroyed while verifying that it is functioning properly.

Until recently, the technical complexity of the missile system and the cost associated with performing "Fly to Buy" testing was not large enough to cause rethinking of the process. However, increasing costs of missile systems and declining defense resources are forcing a re-evaluation of this type of destructive lot acceptance testing. Other more cost-effective testing methods must be found to determine the quality of missile lots.

One possible alternative to this problem is to assess the missile's quality through tests involving computer simulations. This process known as Hardware-in-the-Loop (HWIL) testing, attempts to simulate the flight of the missile without actually requiring it to be fired or destroyed. In this case the actual sample missile would be attached to a computer via a cable tied to as many of the key components of the system as safely practical. A computer simulation of an actual acceptance test scenario could then be run that exercises the missile in a manner similar to an actual live firing against a specified target. The computer collects the data, analyzes them and assesses the results in terms of the lot acceptance criteria.

No specific Government methodology exists that addresses the prospect of simulating missile fights via this HWIL process for lot acceptance. Currently there is no other Army millimeter wave HWIL facility which can accommodate "live" missile rounds. This would require the construction of a separate facility that could perform this type of testing.

D. PURPOSE.

The purpose of this thesis is to explore and evaluate the current Longbow HELLFIRE Lot Acceptance Plan against the conventional "Fly to Buy" methodologies to determine what advantages have been gained using a HWIL simulation for this process and what still remains to be accomplished in order to use this new process effectively.

E. APPROACH.

Because the Longbow HELLFIRE Quality Assurance Lot Verification Test (QALVT) plan is a one of a kind test plan that still is in its draft form, it will be necessary to consider past plans that preceded it to fully understand and appreciate the advantages it presents.

The approach used in conducting this analysis involves first providing the background information leading up to the establishment of an HWIL simulation method. This will be discussed and provided in Chapters I & II. Next the traditional "Fly to Buy" methodology will be discussed in Chapter III, to provide the reader with a basis of understanding of the key requirements involved in conducting prior lot acceptance testing and the whole lot acceptance procedure in general. This will also serve to outline the development of the HWIL simulation method.

The current draft HWIL Simulation Plan will be introduced in Chapter IV, and its differences highlighted from its predecessor the "Fly to Buy" methodology. In Chapter V the HWIL simulation method is analyzed to quantify its benefits and deficiencies. A conclusion to the analysis is provided in Chapter VI. Finally, in Chapter VII, suggested modifications and alternatives (including possible contractual language) of the HWIL methodology are discussed.

II THE NEED FOR HARDWARE IN THE LOOP (HWIL) ACCEPTANCE TESTING

A. BACKGROUND.

In FY 1992, the Air-to-Ground Missile System (AGMS) Project Office, which includes HELLFIRE, HELLFIRE II, and Longbow HELLFIRE, solicited a proposal from the United States Army Test and Experimentation Command, Redstone Technical Test Center (USATECOM RTTC) to develop an alternative method for performing lot acceptance testing on Longbow HELLFIRE Missiles during Low-Rate Production and subsequent Full-Rate Production. Prior lot acceptance testing had been performed exclusively through the use of "Fly to Buy" (FTB) methodology, where a lot sample of 4 to 10 missiles per month were flight tested at Eglin AFB to determine acceptance or rejection for the remainder of the missiles in each lot. In the intervening years between the production of HELLFIRE II and the development of Longbow HELLFIRE, there has been a significant rise in the unit cost of each missile round. The conventional "Fly to Buy" lot acceptance program would require considerable additional resources. An HWIL simulation based testing program will reduce the lot acceptance testing costs.

B. UNITED STATES ARMY MISSILE COMMAND (USAMICOM) POLICY # 702-5.

The Commanding General of USAMICOM has directed that weapon system acquisition planning will consider the principal items expressed in Quality Assurance Lot Verification Testing (QALVT) before making a final determination as to what type of requirements will be included in the final missile lot acceptance plan. The contents of this directive was set forth in MICOM POLICY No. 702-5, dated 16 May 1990.

The application of this policy is based on three principal decision factors: 1) unit cost of missile less than or equal to $ 200k, 2) production rate of at least 50 units per month, 3) estimated QALVT less than 5% of the procurement cost (see Figures # 3, 4, & 5, U.S. Army QALVT decision Criteria)[2].

C. ASSUMPTIONS AND TRADE-OFFS.

The Air to Ground Missile System (AGMS) Project Office and USATECOM RTTC have performed an analysis of the perspective factors and trade-offs involved in implementing a HWIL lot acceptance program versus a traditional "Fly to Buy" (FTB) program.

This analysis considered the two alternatives available to Longbow HELLFIRE (LBHF) as well as the historical data provided by the earlier HELLFIRE I. In all cases, it was assumed that all FTB flight testing would be conducted at

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[2] US Army Missile Command Policy #702-5, 16 May 1990.

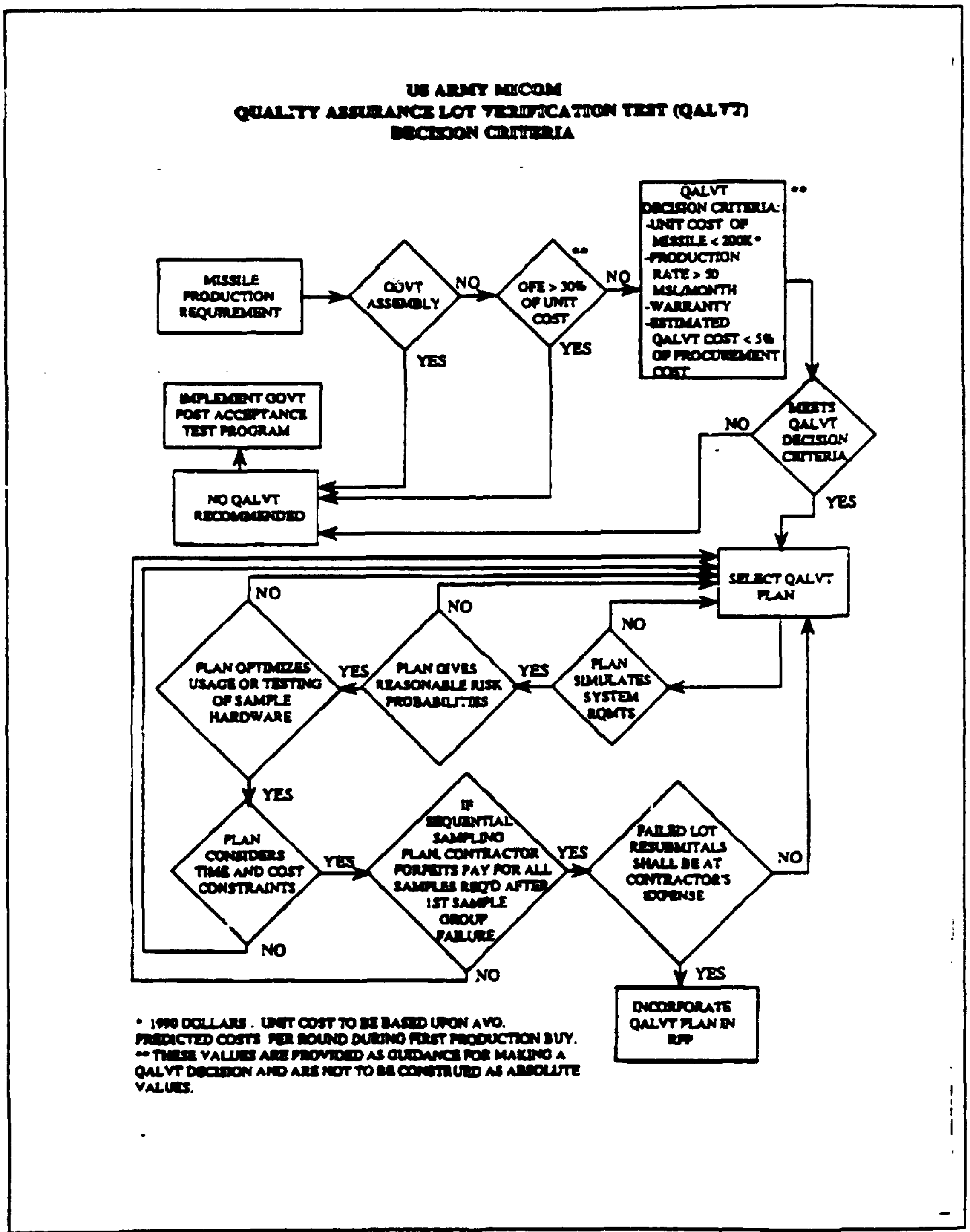
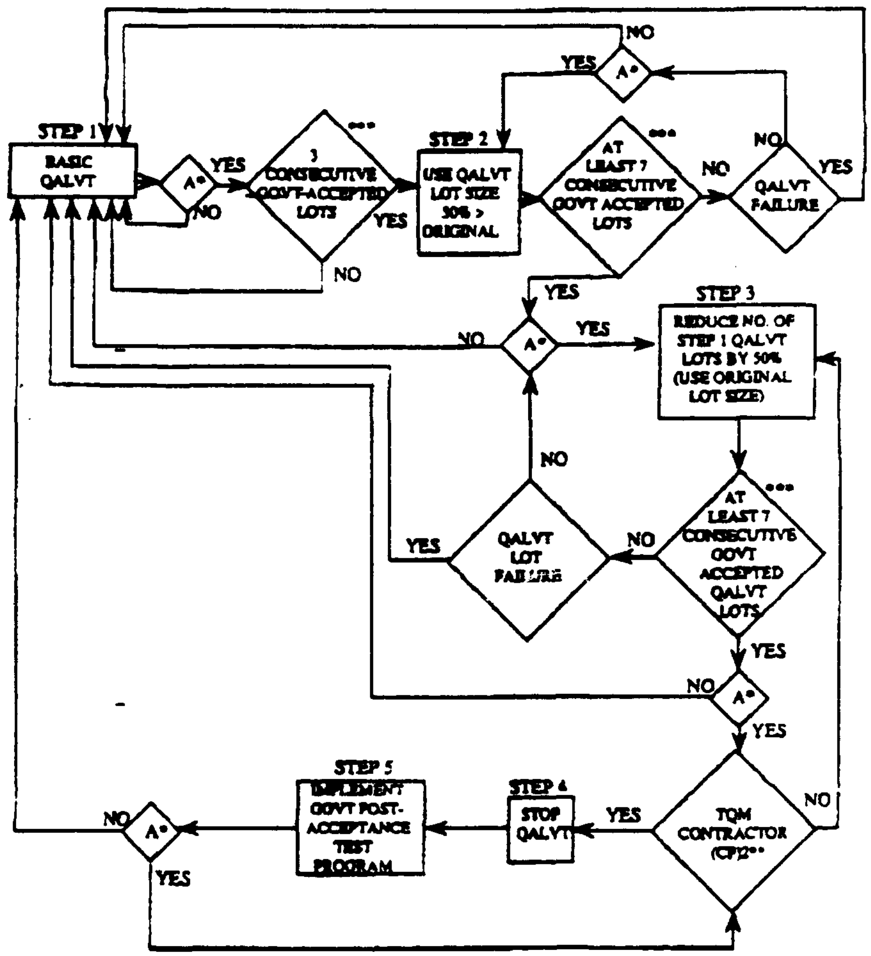


Figure 3 MICOM Policy #702-5, Decision Criteria

QALVT
IMPLEMENTATION AND CORRECTION



* SEE NEXT PAGE
** CONTRACTOR PERFORMANCE CERTIFICATION PROGRAM (CP)2 (SEE AMCR-702-9)
*** CONSECUTIVE LOTS ACCEPTED BY THE GOVT ARE BASED ON THE FIRST SUBMITTAL AND DO NOT INCLUDE RESUBMITTALS FOR THE PURPOSE OF THIS POLICY

Figure 4 MICOM Policy #702-5, Decision Criteria (cont.)

QUALITY ASSURANCE LOT VERIFICATION TESTING (QALVT) CRITERIA FOR MEETING "DIAMOND A" (WHICH ALLOWS PROGRESSION TO THE NEXT STEP IN THE QALVT LOGIC DIAGRAM)

1. QUALITY PROGRAM IN ACCORDANCE WITH MIL-Q-9858.
2. GOVERNMENT APPROVED STATISTICAL PROCESS CONTROL (SPC).
3. SUPPLIER RATING PROGRAM IN ACCORDANCE WITH MIL-STD-1535.
4. LAST PRODUCT ORIENTED SURVEY (POS) SCORED GREATER THAN 8.0.
5. NO CATEGORY 1 QUALITY DEFICIENCY REPORT (QDR) RECEIVED IN THE LAST 12 MONTHS.
6. SIX OR LESS CATEGORY 2 QDRs RECEIVED IN THE LAST 12 MONTHS.
7. NO MAJOR HARDWARE DESIGN CHANGES (SUCH AS PRODUCT IMPROVEMENT PROGRAMS) SINCE THE START OF QALVT STEP 1.
8. TEN OR FEWER MAJOR OR CRITICAL RFDs/RFWs DURING LAST 12 MONTHS.
9. NO MAJOR CHANGES IN FACILITIES, TOOLING, TEST EQUIPMENT OR PRODUCTION PROCESSES SINCE THE START OF QALVT STEP 1.
10. RECEIVING INSPECTION YIELDS GREATER THAN 93 PERCENT DURING THE LAST SIX MONTHS.
11. IN-PROCESS INSPECTION YIELDS GREATER THAN 93 PERCENT DURING THE LAST SIX MONTHS.
12. INTERNAL CONTRACTOR QUALITY AUDIT DATA ARE AVAILABLE TO THE GOVERNMENT AND CONTRACTOR AGREES TO UNANNOUNCED GOVERNMENT AUDITS.
13. MISSILES ARE WARRANTED.
14. NO POST-ACCEPTANCE FLIGHT FAILURES OF WARRANTED MISSILES.

NOTE: ITEMS 1 THROUGH 14 ABOVE ARE PROVIDED FOR GUIDANCE AND MAY BE MODIFIED OR CHANGED THROUGH CONTRACT NEGOTIATION.

Figure 5 MICOM Policy 702-5 Decision Criteria (cont.)

Eglin Air Force Base (EAFB), Alabama. The primary factors inthe development of the assumptions involved in this analysis process were as follows:

Unit Costs:

- HELLFIRE cost per missile....................$ 20k
- Longbow HELLFIRE (LBHF) cost per missile.....$ 300k

  @ Low Rate Initial Production (LRIP).

Test Programs:

- HELLFIRE Lot Acceptance Testing: (FTB) @ 4-10 missiles per month.
- Longbow HELLFIRE (LBHF) Lot Acceptance Testing: (FTB) @ 4-10 missiles per month.
- Longbow HELLFIRE HWIL Simulation: 4 live fires per year and up to 20 missiles simulated flight testing per month.

Facilities:

- Facility for the HWIL Simulation: $ 5.8 million (a one time cost). The actual building and instrumentation.

Labor:

- Personnel needed to run this facility for one year:

estimated at approximately $0.8 million.

With these factors in mind, a trade-off analysis was performed using costs for four missiles with the results portrayed in Table 2-1 Production/Acceptance Analysis[3].

The total savings projected under a HWIL simulation lot acceptance test program would represent cost savings of $13.55 million per year over a conventional "Fly to Buy" program. Even including the $5.8 million necessary for providing for the HWIL simulation facility, the payback period under this assumption would be less than one year.

Table 2-1, PRODUCTION/ACCEPTANCE ANALYSIS.
(in $ millions per year)

	HELLFIRE FTB	LBHF FTB	HWIL SIM.
MISSILE COST[1]	$1.15	$14.40	$1.20
EAFB SUPPORT	$0.72	$0.72	$0.06
RTTC SUPPORT	$0.53	$0.53	$0.44
SYS. SIM SUPPORT	$0.00	$0.00	$0.40
TOTAL	**$2.40**	**$15.65**	**$2.10**

Notes: 1. HWIL SIM. missile costs represent the cost of hook-up and processing of sample missiles through the computer test facility and returning them to their original configuration.

The HELLFIRE FTB column indicates approximately what AGMS pays per year for the HELLFIRE I "Fly to Buy" program, and also indicates where the true cost growth in FTB actually lies, namely, missile cost. This total amount includes

[3] Johnson, J., Memorandum for AGMS, "All Up Round Test Facility", 18 April 1994.

missile cost, range support, and pre-flight support. The Longbow HELLFIRE "Fly to Buy" column indicates what the cost would be if the AGMS Office implemented a similar "Fly to Buy" program with just four missiles per month, even though this method might require up to ten missiles to complete.

D. HWIL SIMULATION REQUIREMENTS.

The requirements imposed on the HWIL facility by AGMS are as follows:

- Functional checkouts of hardware and software interoperability of the missile.
- Test must provide a confidence equal or better than FTB, that missile lots are good or bad.
- Must be non-destructive.
- Must perform testing at the All-Up-Round (AUR) level.
- Must consider environmental conditioning.
- Number of required missiles must be significantly lower.

Testing at the All-Up-Round level, refers to conducting a test at the complete, assembled system level. AUR would not allow components of the system to be disassembled to accommodate testing.

The facility required for HWIL testing would also have to have specific requirements. These would include the following items:

- The HWIL facility be located at Redstone Arsenal

(RSA).

- Capable of Vibration & Environmental testing.
- Capable of handling a Longbow HELLFIRE All Up Round (AUR).
- Meet safety requirements.

Provide cost effective operation.

E. THE SIMULATION/TEST ACCEPTANCE FACILITY.

The Simulation/Test Acceptance Facility (STAF) is the Hardware-in-the Loop facility being developed at RSA by the U.S. Army Test and Evaluation Command (USATECOM) Redstone Technical Test Center (RTTC) and the U.S. Army Missile Command (USAMICOM) and System Simulation and Development Directorate (SSDD). This facility is the only facility in the U.S. capable of performing nondestructive HWIL tests on "live" production and developmental missiles at the millimeter wave frequencies. A diagram of the facility is shown at Figure 6. This facility is currently under construction at RSA on the north-eastern side of Test Area #1. This facility includes the following equipment, buildings and hardware:

1. Bunker.

This structure is approximately 2,000 square feet that features a test item room, a test chamber and a computer room. The test item room contains the compact missile test set and the environmental chamber for conditioning missile rounds prior to testing. The test chamber contains the missile under

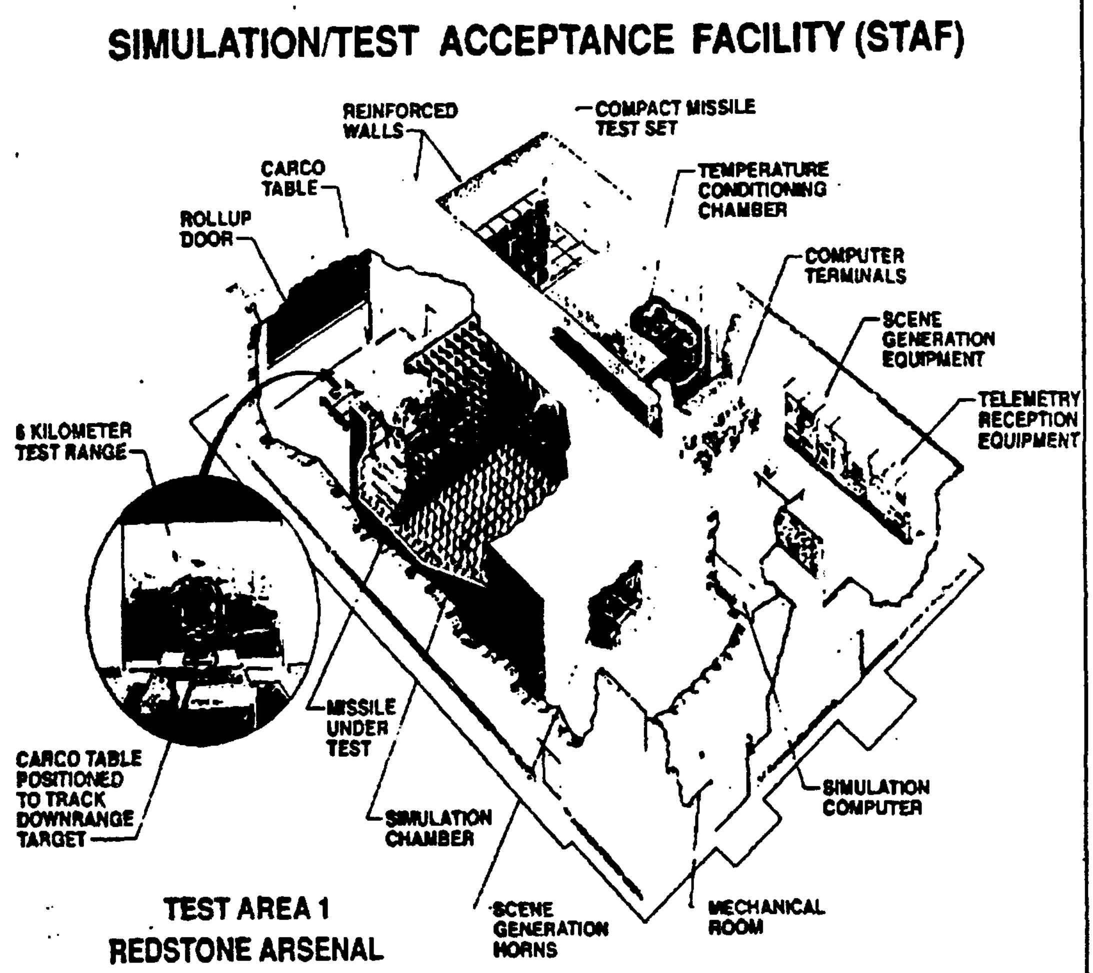


Figure 6 Simulation/Test Acceptance Facility Layout

test, the Three Axis Rotational Flight Simulator (TARFS), anechoic chamber, and the target generator horns of the millimeter wave target simulator. The computer room contains the target generation equipment and instrumentation, telemetry instrumentation, simulation computer, and the data analysis terminals (for inert rounds). There will be a roll-up door in this structure facing down range that will allow actual target acquisition and tracking, if desired, down the long axis of the TA-1 range. This will allow the actual tracking of a variety of real world target vehicles with actual production missiles, at ranges up to approximately 6km.

2. Target Generator.

The target generator system will intercept the millimeter wave signal transmitted by the missile, delay the signal in time to simulate the range to the target, tap delay the signal to simulate target range extent, place proper doppler shift on the signal to compensate for relative movement and return the signal to the missile in real-time on a pulse for pulse basis.

3. Three Axis Rotational Flight Simulator (TARFS).

The TARFS will provide a mounting structure for the missile in the test chamber. It will additionally provide real-time missile flight motion in pitch, yaw, and roll to simulate the missile's actual fly out to the target along its own trajectory. The missile fin position will be monitored and fed back into the simulation in order to control the TARFS position.

4. Telemetry.

All missile and STAF data will be collected and time tagged to allow for a real time "quick look" and post mission data analysis.

5. The Simulation Computer System.

The simulation computer system will consist of two computer systems; a control computer and a modeling computer. The control computer will run the 6 Degrees Of Freedom (6-DOF) program, facility control software, perform inputs and outputs to the modeling computer and interacts with the user. The modeling computer simulates the complex signature of the target subject using parallel processing techniques.

6. Compact Missile Test Set.

This test set will perform the majority of the open loop testing and characterization of each missile round prior to entering into simulation testing. This test set will expose obvious flaws or defects in each missile prior to this testing and prevent wasting valuable simulation time on defective rounds.

III THE EXISTING "FLY TO BUY" METHODOLOGY

A. INTRODUCTION.

The purpose of the "Fly to Buy" Methodology is to determine within an acceptable level of statistical confidence, that the Government is purchasing (in lot size quantities) a product that is reasonably reliable and defect free. In the case of missile procurement, this is usually accomplished after destructively testing the lot sample and comparing the results against pre-established acceptance criteria. The sample size required to accomplish this task is related to the lot size and the confidence interval required. Since most missile systems tend to be quite expensive, this can be very costly in the long run. Consequentially, a sequential sampling plan is usually developed that reduces the average number of missiles tested yet satisfies the requirements. These plans are divided into several stages which specify a certain quantity and an acceptance/rejection criteria. Often these plans, depending on the lot size and confidence required, will specify that testing be continued and that another stage of testing be conducted up to a pre-determined quantity. At the end of the final stage, a decision will be made to accept or reject the lot and no other testing will be continued for the lot.

B. THE HELLFIRE LOT ACCEPTANCE PROGRAM.

1. Purpose.

The purpose of the HELLFIRE Lot Acceptance Program is to provide confidence that HELLFIRE missiles meet the specified performance and reliability requirements of the production contract[4].

2. Background.

a. Sampling Plan Characteristics.

This plan is intended to provide a method for performing lot acceptance by prescribing an Acceptable Quality Level (AQL) for the production process. This AQL is used to determine the sample size for the sampling inspection. The AQL is the largest allowable percent of defective items of a satisfactory process average. This sampling plan and its AQL are chosen in accordance with the risk assumed, as defined in the contract. Thus, the AQL is the designated value of percent defective for which lots will be accepted most of the time by the sampling procedure to be used. The sampling plan is usually arranged so that the probability of rejecting a lot when the process average is at the designated AQL value is not larger than a preassigned small value (eg. 0.10). This is the producer's risk. The producer's risk may vary slightly with the sample size.

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[4] The HELLFIRE II Modular Missile System QALVT Plan, USAMICOM, July 1989, is the primary source of information for this chapter.

b. Operating Characteristics Curves.

In military standard lot acceptance testing documents, the operating characteristic curves (OC curve) for normal inspection, indicate the percentage of lots or batches which may be expected to be accepted under the various sampling plans for a given process quality. These OC curves are normally shown for single sampling; curves for double and multiple sampling are matched as closely as practicable. The OC curves shown for AQLs greater than 10.0 are based on the Poisson distribution and are applicable for defects per hundred units inspection; those for AQLs of 10.0 or less and sample sizes of 80 or less are based on the binomial distribution and are applicable for percent defective inspection; those for AQLs of 10.0 or less and sample sizes larger than 80 are based on the Poisson distribution and are applicable either for defects per hundred units inspection, or for percent defective inspection (the Poisson distribution being an adequate approximation to the binomial distribution under these conditions). Tabulated values, corresponding to selected values or probabilities of acceptance (P_a, in percent) are given for each of the curves shown. These tables are also given for tightened inspection processes. An example of a typical OC curve is shown at Figure 7.

TABLE X-F—Tables for sample size code letter: F

CHART F - OPERATING CHARACTERISTIC CURVES FOR SINGLE SAMPLING PLANS

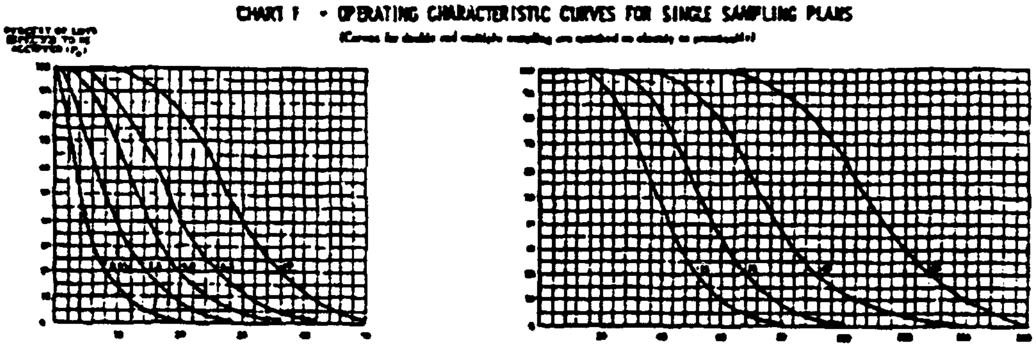

TABLE X-F-1 - TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR SINGLE SAMPLING PLANS

P_a	Acceptable Quality Levels (normal inspection)																
	0.65	2.5	4.0	6.5	10	0.65	2.5	4.0	6.5	10	15	X	25	X	40	X	65
	p (in percent defective)					p (in defects per hundred units)											
99.0	[illegible]	[illegible]	[illegible]	[illegible]	8.75	[illegible]	[illegible]	2.10	4.12	[illegible]	14.5	17.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
95.0	0.256	1.41	4.22	7.14	14.6	[illegible]	1.78	[illegible]	[illegible]	13.1	19.0	22.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90.0	0.525	[illegible]	5.44	[illegible]	[illegible]	0.527	[illegible]	[illegible]	[illegible]	15.6	[illegible]	27.3	[illegible]	43.2	[illegible]	[illegible]	[illegible]
75.0	1.43	[illegible]	8.70	[illegible]	21.6	1.44	[illegible]	[illegible]	12.7	[illegible]	[illegible]	[illegible]	43.1	[illegible]	[illegible]	[illegible]	[illegible]
50.0	[illegible]	[illegible]	[illegible]	[illegible]	27.9	[illegible]	[illegible]	13.4	18.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25.0	6.70	12.9	18.7	24.2	34.0	[illegible]	13.5	19.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10.0	10.9	18.1	24.5	30.4	41.5	11.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	77.0	[illegible]	[illegible]	[illegible]	[illegible]
5.0	[illegible]	21.6	[illegible]	34.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	97.2	[illegible]	[illegible]	[illegible]
1.0	[illegible]	[illegible]	[illegible]	47.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	114	[illegible]	[illegible]	[illegible]
	1.0	4.0	6.5	10	X	1.0	4.0	6.5	10	15	X	25	X	40	X	65	X
	Acceptable Quality Levels (tightened inspection)																

Figure 7 Typical OC Curve for Lot Acceptance Purposes

3. HELLFIRE Lot Acceptance Definitions and Procedures.

Missile - A missile shall consist of one LBHF High Explosive Anti-Tank (HEAT) missile as defined by Missile Specification (MIS-SPEC) MIS-44430 or MIS-42560.

Test Article - The test article will be a HFLB HEAT production missile which has been selected for sample testing.

Lot - A lot shall consist of the production quantity for a given month which has been produced under the same processes. In all cases, missile lot sizes shall be subject to the constraints of homogeneity with respect to changes in the processes, configuration changes, deviations or waived hardware, etc., which may materially affect performance of the end item. The Government reserves the right to combine monthly build lots when necessary/appropriate.

Lot Sample - A lot sample is the quantity of ten missiles randomly selected from a lot build of 100 missiles or more which will be environmentally conditioned and then tested for the purpose of lot acceptance or rejection. Each lot sample of ten missile is further divided into three subgroups consisting of lot sample test article numbers 1-4, 5-8, and 9-10 respectively.

4. Sampling Procedure.

As indicated above, in the case of HELLFIRE, ten missiles will be randomly selected from each lot build, and shall be delivered to Redstone Arsenal (RSA), Alabama, for environmental conditioning and then shipped to Eglin Air Force Base (EAFB) for the actual missile flight testing. The Government then shall accept or reject the entire lot of missiles (which is anticipated to be roughly one month's production) based on the following sequential sampling plan:

Table 3-1, SEQUENTIAL SAMPLING PLAN.

No. Msls Tested	No. Msl Failures (Cumulative)		
	Accept Lot	Continue Testing	Reject Lot
4	0	1	2
8	1	2	3
10	2	--	3

In addition to the ten missiles selected for testing, two contingency missiles shall be selected from each lot. These two contingency missiles will be used in the event that any of the ten test articles are damaged or otherwise unsuitable for testing. This will prevent disrupting the test process if one or two missiles have to be substituted for these reasons.

Smaller samples shall be selected from lots of less than 100 units per month (a distinct possibility in the case of diminishing procurement funding or program stretch outs). The minimum number of missiles to be selected under these conditions is as follows in Table 3-2 below.

Table 3-2, SMALL SAMPLE SIZES.

LOT SIZE	LOT SAMPLE SIZE
1-10	1
11-25	2
26-49	3
50-99	5

The Government shall identify to the contractor missiles (by serial number) which have been selected for QALVT testing at the time the missiles have successfully completed final inspection at the production facility.

After these missiles are identified to the contractor as test articles, the contractor will then seal the missile containers with contractor furnished seals, and shipped to RSA for testing. The contingency missiles may be held at the contractor facility or shipped with the test articles to RSA.

The missiles selected for lot sample testing shall be counted as a portion of the deliverable quantity of the applicable accepted lot. If any seals or containers are broken, the Government reserves the right to require replacement of the missile in the lot sample with a contingency missile. The remainder of the lot of missiles which have not been selected for testing at RSA, shall be packed in missile containers and placed in secured storage until completion of the lot acceptance testing, for which they are part, is complete. The serial number of each missile for each lot shall be provided to the Government at the time it is placed into secured storage.

Once a selected test article has been identified to the contractor, no further tests, adjustments, or repairs shall be performed except as authorized by the Government. Test articles rejected on arrival at RSA shall be dispositioned by pre-flight nonconformance procedures. The contractor shall test missiles at RSA on the HELLFIRE Missile Compact Test Set (HMCTS) in accordance with procedures specified in the QAVLT Plan and perform pre-flight check out at EAFB on the HELLFIRE Compact Firing Test Set. The Government reserves the right to omit any portion of the lot acceptance test, including environmental tests, of any or all of the sample missiles. After Government inspection at RSA, test articles shall be stored in a Government security locked area.

5. **Flight Testing.**

After Government inspection and acceptance procedures at RSA have been completed and prior to shipment to EAFB, the lot sample missiles will be subjected to Captive Flight Vibration (CFV) and one subgroup will be environmentally conditioned at RSA, in accordance with the lot acceptance plan and the applicable missile specifications.

Upon completion of these tests and environmental conditioning at RSA, the missiles will be transported to EAFB for pre-flight and firing per Table 3-3.

TABLE 3-3, TEST FIRING MATRIX.

LOT #	TEST ART	PROFILE	MODE	RANGE	COND.
6n+1	1	INDIRECT LOW	LOAL	L	AMB
6n+1	2	INDIRECT HIGH	LOAL	L	AMB
6n+1	3	DIRECT	LOBL	M	AMB
6n+1	4	DIRECT	LOBL	M/8°	AMB
6n+2	1	INDIRECT HIGH	LOAL	L	COLD
6n+2	2	INDIRECT LOW	LOAL	M	COLD
6n+2	3	DIRECT	LOAL	S	COLD
6n+2	4	DIRECT	LOBL	M/8°	COLD
6n+3	1	INDIRECT LOW	LOAL	S	HOT
6n+3	2	DIRECT	LOBL	S/8°	HOT
6n+3	3	DIRECT	LOAL	M	HOT
6n+3	4	INDIRECT HIGH	LOAL	M	HOT
6n+4	1	DIRECT	LOAL	M	AMB
6n+4	2	INDIRECT HIGH	LOAL	M	AMB
6n+4	3	INDIRECT LOW	LOAL	S	AMB
6n+4	4	DIRECT	LOBL	S/8°	AMB
6n+5	1	DIRECT	LOBL	M	COLD
6n+5	2	INDIRECT HIGH	LOAL	M	COLD
6n+5	3	INDIRECT LOW	LOAL	L	COLD
6n+5	4	DIRECT	LOBL	S/8°	COLD
6n+6	1	DIRECT	LOBL	M	HOT
6n+6	2	DIRECT	LOBL	M/8°	HOT
6n+6	3	INDIRECT HIGH	LOAL	L	HOT
6n+6	4	INDIRECT LOW	LOAL	L	HOT

Where n = 0, 1, 2, 3....., Lock-on can be either before or after launch (LOBL or LOAL) and Range which will be at short (up to 2km), medium (2-5) and long (+5), can include an 8° offset. Offset is the deviation from the straight line trajectory that the missile selects (either right or left) to help it to distinguish the actual target from possible background clutter. Conditioning (COND.) represents the environmental temperature conditioning either at ambient (AMB), cold (-45 F) or hot (+145 F).

The procedures used to conduct the actual firing at Eglin AFB will be controlled by that installation. Missiles will be transported, inspected and prepared for firing. This will involve conducting a test readiness review (TRR) to insure that all the test requirements, range support, instrumentation, and safety considerations have been satisfied prior to actual missile firing.

The objective of this specified missile firings is to mix two ranges, all modes, offsets, with varying degrees of difficulty on each block of the four firings so that all missile specifications will eventually be tested when this table is completed. There are a few limitations. They are: 1) Only two firing ranges (distances) can be instrumented on the firing range at one time, and 2) All firing from any one lot will be performed at the same temperature conditioning for all test articles. The Government may require the contractor to fire at any of the conditions in the matrix above or any combination of conditions that are in accordance with the appropriate Military Specification (MIL-SPEC). Prior to firing, the Government and contractor shall confirm that all firing equipment and associated range equipment are in proper working condition and calibrated.

6. Scoring.

All test articles shall be scored as either a: 1) Success, 2) No Test, or 3) Failure, in accordance with the following criteria.

a. Pre-flight Nonconformance:

Any nonconformance of a test article or to Test Design Package (TDP) requirements discovered during inspection (including nonconformances discovered prior to, during, or after environmental testing of missiles at RSA or pre-flight checkouts at EAFB) shall constitute cause for failure of the test article and may be cause for lot rejection. The following procedure will apply in determining the extent of further testing on the subject lot:

- Testing of a missile shall be stopped at the point any failure or nonconformance is discovered and a preliminary analysis shall be made by the contractor and submitted to the Government within 24 hours.

- The Government will then determine whether this missile will continue through test and be fired or whether it will be failed and returned to the contractor for failure analysis and future production.

- If a missile exhibits a pre-flight nonconformance and the Government elects to continue testing that missile, that particular pre-flight nonconformance shall be scored a "no test".

- If the Government determines from the failure analysis that the pre-flight nonconformance will or is uncertain it will have an impact on the flight test parameters, the missile will be scored a safety or reliability failure as appropriate.

Based on the preliminary analysis of the pre-flight nonconformance, the Government and contractor may jointly elect to continue testing of the lot. A determination to continue shall not relieve the contractor of the responsibility to correct the failure condition in all missiles, as deemed necessary by the Government.

b. No Test

A no test may stem from a variety of causes and sources related to the missile under test or circumstances surrounding these tests. They will include areas resulting from:

- A malfunction of equipment other than the test article or proven post launch environments which causes the missiles to experience conditions outside of those specified in the Missile Specification (MIS-SPEC).

- Failures induced by Government personnel error or failures induced by errors of those authorized to act for the Government, either deliberate or inadvertent, or operation beyond prescribed limits.

- In the event that the contractor aborts a missile launch and the subsequent analysis proves that the missile did not experience an anomaly, the missile will be scored a "no test". The contractor shall pay all retest costs and the Government will notify the contractor of the acceptance or rejection of the lot within 45 additional calendar days beyond the time identified in the lot acceptance plan.

- Although a failure did not occur, the missile displays a property not previously observed and is, therefore, of special interest. It is anticipated that, if left in the test sequence, this missile will pass all tests and when launched will fly successfully and hit the target within the required accuracy thus fulfilling QALVT requirements. If the missile is permitted to remain in the test sequence all the way through to a successful launch, the opportunity to determine the cause of this newly observed property will be conducted by the appropriate range personnel. If this occurs prior to launch, a Government/contractor decision shall be made regarding further testing of this missile.

c. *Failures.*

Failure: Any malfunction (not meeting the no test criterion) which would preclude the missile from performing within the requirements of the MIS-SPEC will be categorized as either a safety or reliability failure as follows:

Safety failures: A lot shall be rejected as a result of one pre-flight nonconformance or missile firing that results in a condition that may be hazardous or unsafe as defined in the Technical Design Package (TDP) or as defined below. A safety failure will have occurred if:

- A warhead detonates prior to the minimum safe arm distance from the launcher of 150 meters.
- An inadvertent launch occurs which is traced to a missile malfunction.
- There is a delay (hang fire) of more than five seconds between the initiation of the firing signal and the ignition of the rocket motor.
- Any event that would endanger the launching helicopter (e.g. major debris thrown in the area by the missile upon launch).

Reliability Failure: Accept/reject criteria for reliability shall be attributed based on the total number of failures. Accept/reject numbers shall be as specified in the sampling plan (see Table 3-1, Sequential Sampling Plan, pg 26). A reliability failure shall have resulted when one or more of the following occurs:

- A missile misses the target. A target miss shall have occurred if an intact missile does not meet the accuracy requirements as stated in the corresponding MIS-SPEC.
- The missile impacts the ground prior to impacting the target.
- The warhead fails to detonate in accordance with the timing requirements of MIS-SPEC.
- The warhead detonates during flight due to a missile malfunction and is not otherwise scored a safety failure.
- A no-fire occurs. A no-fire is defined as failure of the missile to fire following application of the firing signal.
- The missile flies a profile other than that preset.
- A pre-flight nonconformance determined to be a reliability failure in accordance with the QALVT Plan.

d. Success.

Success: All missile flights not scored as a no-test or failure will be scored as a success. All available test data and flight hardware debris shall be made available o the contractor as soon as practical; visual examination of impact debris and recovery of the maximum amount of missile hardware debris, that can safely be handled, shall be allowed prior to destruction of the remainder of the hazardous components (if deemed feasible by the Explosive Ordinance Disposal unit (EOD)), contingent on approval by the on-site EOD representatives. Scoring of missile launches as success, failure, or no-test will be accomplished by the Government.

7. Acceptance/Rejection Criteria.

Acceptance or rejection of a lot is based on pre-flight inspection and tests at RSA and EAFB and flight acceptance tests on a sample of missiles randomly selected by the Government from each lot and scored in accordance with the lot acceptance plan. In addition missiles will not be accepted until all waivers, deviations, Engineering Change Proposals (ECPs), or other issues affecting a lot are resolved to the Government's satisfaction.

Upon accepting a lot of missiles, the contractor shall deliver to the Government all remaining lot sample missiles, (including contingency missiles) not flight tested. Missiles which have been disassembled/repaired in failure analysis and have been subjected to lot acceptance captive flight and vibration testing will be made functional, by completing a functional baseline test at the lot temperature designated at RSA and accepted for retirement at RSA.

8. Resubmittal Criteria.

Lots which fail to pass the acceptance criteria may be resubmitted by the contractor unless an alternative plan of action for the lot acceptance of missiles is agreed upon between the Government and contractor. Failure analysis will be conducted and deficiencies corrected from the initial submittal prior to the resubmittal as described above. A failed lot may be resubmitted a maximum of two times. All scoring and rejection criteria will remain the same except for adjustments made in the quantity of test articles required for decreased lot sizes.

9. Contractor Liability.

When a lot sample fails the acceptance criteria and is rejected by the Government or when a lot meets the acceptance criteria and one or more failures occur, the contractor shall perform failure analysis and shall submit a detailed report describing the deficiencies in performances which resulted in rejection or failure and the action necessary to correct and prevent recurrence of the deficiencies. The contractor's report shall be prepared in accordance with the data item reporting requirements contained in DI-RELI-80253.

In the event of a failed lot, additional lots shall not be submitted for acceptance until corrective action has been approved by the Government. Also, testing may be suspended at the Government's option on any test articles located at RSA or EAFB.

10. Responsibility for Retesting Rejected Lots.

In the event lots are rejected, any and all expenses associated with failure analysis, replacement hardware, rework, reinspection, packaging, packing, handling, transportation, and retest shall be borne by the contractor. The foregoing expenses are inclusive of the cost of replacement of missiles, Government Furnished Equipment (GFE), cost of range operations, environmental conditioning, and additional failure analysis. With respect to retest costs assuming a resubmittal of 4 missiles, the contractor shall reimburse the Government in the amount of $4,000 for each missile environmentally conditioned at RSA, and $10,000 for each missile flown in each resubmitted lot test sample. At the contractor's option and expense, the remaining test missiles from a rejected lot may be returned to him. Replacement missiles will be in the same quantity expended in initial test, retest, and those rendered non-deployable due to environmental conditioning less the ten (10) missiles allocated for each lot tested in the acceptance plan and contingency missiles that replace "no test" missiles.

11. Responsibilities.

a. *Contractor Representative.*

The contractor representative is responsible for technical support effort in observing, analyzing, and supporting program plans and procedures to meet program milestones and objectives. Additionally, he will coordinate with other supporting agencies to insure mission support requirements are fulfilled in a timely manner. The contractor shall provide a single individual at RSA and EAFB who shall act as the point of contact for all decisions related to local test activities. The contractor may participate in all test mission planning sessions, Mission Readiness Reviews (MRR), data reviews, and/or briefings.

The contractor shall provide all missile round information and simulation results required to describe expected flight performance of the missile. This shall include nominal flight trajectories and expected three sigma variation bounds of this trajectory. The contractor may monitor the launch and shall assist the Government in solving any problem areas which may arise due to missile malfunction.

In case of a suspected missile "failure" or "no test" the following activities shall be performed:

- The contractor shall perform a failure analysis on any test article which are suspected failures or "no tests". Results of this analysis and recommendations for further activities shall be prepared in a Failure Analysis Report in accordance with data item reporting requirements contained in DI-RELI-80253.

- The contractor shall prepare a Corrective Action Plan in accordance with DI-RELI-80254 for all failures which result in the rejection of a missile lot. This plan shall describe all activities and actions planned by the contractor to solve the missile failure problem. Government approval of the Corrective Action Plan is required prior to implementation.

In the case of a rejected lot, the contractor shall develop and prepare a plan for lot resubmission in accordance with DI-RELI-80254 indicating the scheduling and activities to be performed to resubmit the lot to the Government for acceptance. Government approval of this plan is required prior to implementation.

b. U.S. Air Force.

<u>U.S. Air Force - Range Support Contractor & Range Support Representative:</u>

The U.S. Air Force Support contractor and representative is responsible for overall flight range operations to include Data Acquisition and Control System operation, test instrumentation, data collection and reduction, missile ready storage and delivery, environmental chamber operation, range security, range safety, conduct of the countdown from upload to launch, missile recovery operations, target complex operations, data and documentary camera operation, laser spot data, and geodetic surveys of missile impact points.

U.S. Air Force - 46th Test Wing - Test Engineer/Coordinator:

The Air Force test engineer/coordinator will be responsible for overall Air Force coordination, management, and scheduling of resources to support missions on Range C-72, the Longbow HELLFIRE flight test range.

U.S. Air Force Range Systems Directorate Representative:

The Range Systems Directorate formally controls all test procedures, instrumentation, and software configuration. No change or variation in procedures or configuration will be made without prior written approval of the Range System Directorate engineering representative. All questions concerning range instrumentation or facility performance, readiness, and utilization will be directed to the Range Systems representative.

No information or data generated at the facility will be released without the representative's Quality

Assurance review. All requests for assistance or support from the Range Operation and Maintenance (O&M) contractor shall be made through this representative. No direction of the O&M contractor shall be made by the missile contractor or other support personnel.

IV THE HARDWARE IN THE LOOP (HWIL) SIMULATION METHOD

A. INTRODUCTION.

As in the case of many areas of Government regulation, lot acceptance has several underlying requirements that must be addressed regardless of the methodology adopted to perform the overall controlling action. This is certainly true for the Longbow HELLFIRE missile. Since several aspects of HWIL will not differ much from those areas already identified in the "Fly to Buy" methodology, only those areas that differ will be addressed. Therefore, the reader can assume that all other areas not specifically addressed will remain the same.

B. LONGBOW HELLFIRE HWIL SIMULATION QALVT.

1. Purpose

The purpose of the Longbow HELLFIRE Quality Assurance Lot Verification Test (QALVT) program is to provide a cost effective means of determining the acceptability of Longbow HELLFIRE production missiles while still meeting the specified missile performance and reliability requirements stated in the contract[5].

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[5] The Longbow HELLFIRE Modular Missile System, Low Rate Initial Production QALVT Plan, USAMICOM, 23 May 1994, is the source of information used throughout this chapter.

2. The QALVT Plan

The Longbow HELLFIRE QALVT plan provides a method to subject a random sample from a lot of Longbow HELLFIRE missiles to a nondestructive, environmentally conditioned, dynamic, mechanical, and functional test through the use of a Hardware in the Loop Simulation that depicts an electronic target similar to those that are anticipated to be encountered under future battlefield conditions. The resulting miss distance would be the primary performance measure.

3. Definitions.

Missile - A "missile" shall consist of one Longbow HELLFIRE HEAT missile as defined in the MIS.

Lot - A lot shall consist of the production quantity for a given month which has been produced under the same conditions utilizing the same processes.

Lot Sample - A quantity of fifteen missiles randomly selected from a lot which will be tested in accordance with the QALVT Plan.

4. Lot Sampling Procedure.

Instead of the ten missiles required for FTB, fifteen missiles shall be randomly selected from each lot and delivered to RSA. These fifteen missiles shall have been previously tested on special inspection equipment, to be determined (TBD), and shall have passed all inspections and tests. The Government may require the identification of all of the contingency missile(s).

While at RSA, the fifteen missiles will be tested in the Simulation/Test Acceptance Facility (STAF). The Government will then accept or reject the entire lot of missiles based on the following simulation sampling plan criteria described in Table 4-1 below.

TABLE 4-1, SIMULATION (HWIL) SAMPLING PLAN.

No. Missiles Tested	Number of Missile Failures		
	Accept	Continue	Reject
6	0	1	2
6	1	2	3
3	2	--	3

Procedures for selection and transportation of these missiles to RSA is basically the same as with the "Fly to Buy" method. Unless physically damaged in transportation, these missiles will be determined to be suitable for testing once they have arrived and been inspected by the Government representative at the STAF facility. And as with FTB method, the missiles selected for lot sample testing will be counted as a portion of the deliverable quantity of the applicable accepted lot.

5. Test Sequence and Pass Fail Criteria.

a. Incoming Inspection.

There is no pass/fail requirement for this test other than the Government visually inspecting the missile for signs of damage due to shipment prior to the actual testing.

b. Perform Portable Missile Test Bench (PMTB) Tests.

This is a system pre-check performed by the contractor utilizing portable test equipment. The actual portable test equipment that will be used to perform this test is anticipated to be fielded in conjunction with the missile system.

c. Perform Limited Vibration Test.

This limited vibration test will be designed to simulate some of the vibration that the missile system would be exposed to if it had been actually fired. The levels of this vibration are to be determined in the future.

d. Missile Preparation.

Missile preparation will consist of removing the precursor door and installing an electrical harness called a "pigtail", in order to connect the internal missile guidance electronics to the HWIL simulator. Additionally, it is anticipated that an external pneumatic gas line will be connected to the fin mechanism to actuate it during the simulation to demonstrate that the fin system is responding properly to guidance commands. However, in order to accurately assess this fin response, it would be necessary to replicate the aerodynamic loading of the fins. This process is a very difficult task to perform in a laboratory environment. Because of the difficulty involved, the decision as to whether or not this will be attempted has not been made at this time.

e. Environmental Conditioning.

All missiles selected from a lot shall be shipped to Redstone Arsenal, but only one subgroup will be initially environmentally conditioned. The environment conditioning will be for 24 hours. The next subgroup from the lot will not begin environmental conditioning until the previous subgroup has been tested and the need to test the second subgroup established. The contractor may select the temperature for the first lot; thereafter, the temperature conditioning sequence will typically continue as follows:

TABLE 4-2, MISSILE ENVIRONMENTAL CONDITIONING.

LOT NO.	SUBGROUP	SAMPLE SIZE	TEMP.
n + 1	1 2 3	6 6 3	AMBIENT
n + 2	1 2 3	6 6 3	COLD (-45 F)
n + 3	1 2 3	6 6 3	HOT (+145 F)
Where n = 1, 2, 3....			

Once environmental conditioning has been completed, the missile will be removed from the chamber and installed on a CARCO[6] table with shroud. The CARCO table is a special test fixture that reduces the effect of unwanted vibration during tests and allows the entire test stand to be moved within the STAF facility test cell.

f. Closed Loop Electronic Tests.

Six flight test scenarios will be simulated by the STAF[7]. Four scenarios will be against Stationary (S) target at ranges from 1.5 kilometers (km) to 7.5km. Two of the stationary target scenarios will be conducted at ranges of 1.5 km and 2.49 km in Terminal Track Acquisition (TTA) and Terminal Track (TT) modes, both with Precision (P) Hand over (P H/O). One will Lock-on Before Launch (LOBL) and the other will Lock-on After Launch (LOAL). The remaining two stationary target scenarios will be conducted at ranges of 6 km and 7.5 km in modes Pre-Terminal Track Acquisition (PTA), Pre-Terminal Track (PTT), TT and Reduced Radar Cross Section (RCS). Both will employ lock on mode LOAL and P H/O.

Two scenarios will be against moving (M) targets at 6km range and will employ LOBL lock on mode. One will employ P H/O with Moving Target Acquisition (MTA) (spotlight), PTT and TT modes while the other employs Non-Precision (NP) H/O with MTA (scan), PTT Ground Evaluation (GE),& TT modes.

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[6] CARCO is the name of the manufacturer who produces this test fixture.

[7] Specific tasks that will be performed within the closed loop tests are described in Appendix B.

These scenarios are outlined in Table 4-3.

The requirement for success is that each missile shall be tested three times (runs) for each scenario. A missile must pass two runs out of these three for each scenario in order to be a success.

The miss distance requirement for each run is 2 x Circular Error Probable (CEP) requirements.

TABLE 4-3, CLOSED LOOP ELECTRONIC TESTS.

SCENARIO	TARGET	RANGE	LOCK ON	H/O	MODES TESTED
1	S	1.5km	LOBL	P	TTA, TT
2	S	2.49km	LOAL	P	TTA, TT
3	M	6km	LOBL	P	MTA spotlight PTT, TT
4	M	6km	LOBL	NP	MTA scan PTT, GE, TT
5	S	6km	LOAL	P	PTA, PTT, TT
6	S	7.5km	LOAL	P	PTA, PTT, TT

The general layout of this closed loop test can be seen at Figure 8 on the following page.

g. Open Loop Tests.

Open loop testing concerns checking other areas of missile system performance that cannot be performed as part of the closed loop segment of the HWIL simulation itself[8]. These areas involve conducting the following tests and tasks:

[8] The specific tasks that will be performed within the open loop tests are described in Appendix B.

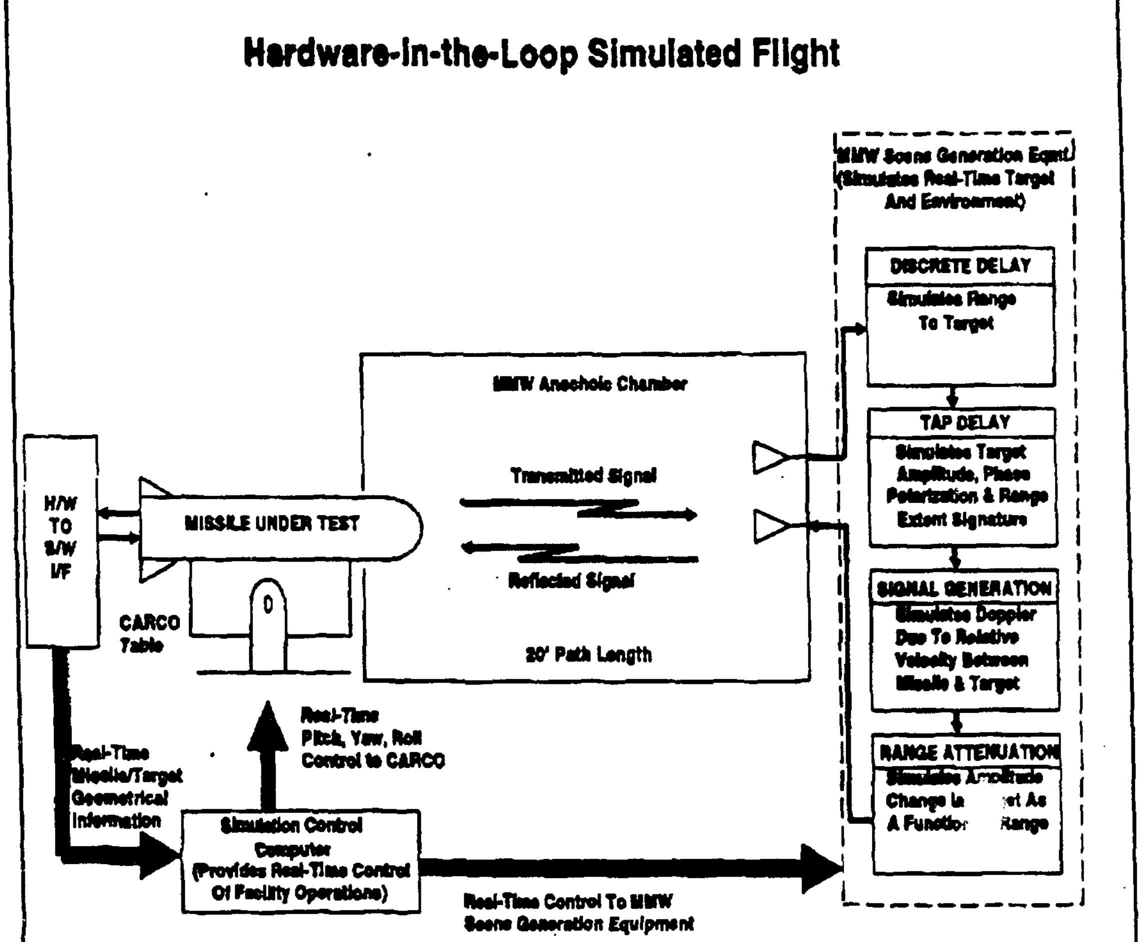

Figure 8 Closed Loop Test Layout

- RF Transit Output Test - in accordance with Longbow HELLFIRE MIS-SPEC-45584, to within minus 4 dB.

- Basic Fin Response Test - This is part of the PMTB test that will be done prior to closed loop tests.

- IMS Performance - Move CARCO table and measure gravity-relative position + 10%.

- Remove shroud and missile from CARCO table.
- Remove pigtail and re-install precursor door.
- Perform PMTB test.

Recertification

Recertification will be in accordance with procedures that will be determined at a later date, but involve insuring that the missile (after completing the lot acceptance test) is placed back in to the same condition it was in prior to the start of testing.

h. Resubmittal Criteria.

Lots which fail to pass the initial testing may be resubmitted by the contractor unless an alternative plan of action for the lot acceptance of missile is agreed upon between the contractor and Government.

Failure analysis shall be conducted and

deficiencies corrected from the initial submittal prior to resubmittal as outlined in the contractor's plan for lot resubmission which will be prepared following the procedures described in DI-RELI-80254. A failed lot may be resubmitted a maximum of two times.

V ANALYSIS

A. INTRODUCTION.

In the process of analyzing the Longbow HELLFIRE HWIL Simulation plan and methodology, several key issues regarding the basic structure and nature of the HWIL methodology come to light. The first one involves the very manner in which the test plan is structured. The issue here being whether or not the concept of Hardware in the Loop testing needs to follow the traditional structure typified by the FTB methodology or even the current HWIL version. This is because many of the reasons for the structure are no longer important to the outcome. Several factors need to be discussed in view of this very pertinent statement and for several reasons:

1) Since HWIL does not require destructive testi of the missile, or its components, the traditional cost saving procedures described in earlier versions of the HELLFIRE QALVT or similar sampling procedures need not necessarily apply to the HWIL simulation.

2) The quantity of test articles needed to perform HWIL testing need not be limited to just that of a minimum quantity necessary to provide a desired statistical confidence that a particular lot is good or bad.

3) In order to insure that this method actually provides an accurate assessment of the true nature of the product, a validation of the system/methodology must be conducted to substantiate, that the process will provide the desired information without an increase in the error probability or that some other undesirable result would occur.

4) Actual missile flights will still be conducted to gather additional test data and to provide a quality check on the entire system (to include those areas that cannot be tested using HWIL, such as the warhead detonation train). The role that these missile flight tests will play in the lot acceptance plan needs to be resolved.

5) How should the contract requirements for lot acceptance testing be altered to take greater advantage of the cost efficiency that HWIL simulation could provide?

With these factors and considerations in mind, it seems prudent that the first step in analyzing the HWIL process, is to quantify/qualify all of the inputs and outputs of the FTB and HWIL simulation processes, and that of the Longbow HELLFIRE missile system that will be tested, and then compare these results to the factors and considerations described above. Finally these results should be compared with the Draft HWIL Simulation QALVT Plan to see what modifications would be warranted. This process should help provide a basis of where or how the current plan could be modified to accommodate better approaches.

Next a method for validating the HWIL simulation should be identified or developed.

B. THE TWO APPROACHES.

1. HELLFIRE (Fly To Buy).

The original "Fly To Buy" methodology was designed to provide an acceptable level of protection for the Government and an acceptable level of risk to the contractor. This acceptable level is based on the anticipated reliability of the system under inspection. In the case of the Longbow HELLFIRE system, this missile system reliability was determined to be 0.94, and the acceptable quality level (AQL) was placed at 0.92. Considering the high cost of the HELLFIRE missile, the plan was structured to achieve a decision as to individual lot acceptability at the end of the least amount of destructive testing. In the case of earlier HELLFIRE missile systems, this led to the development of the 4-4-2 multi-stage plan described in Chapter III.

This plan can be evaluated via an OC curve that presents the inherent probability that the lot of missiles will be accepted based on the test results of the sample of missiles tested. The OC curve for the original FTB plan is depicted below at Figure 9.

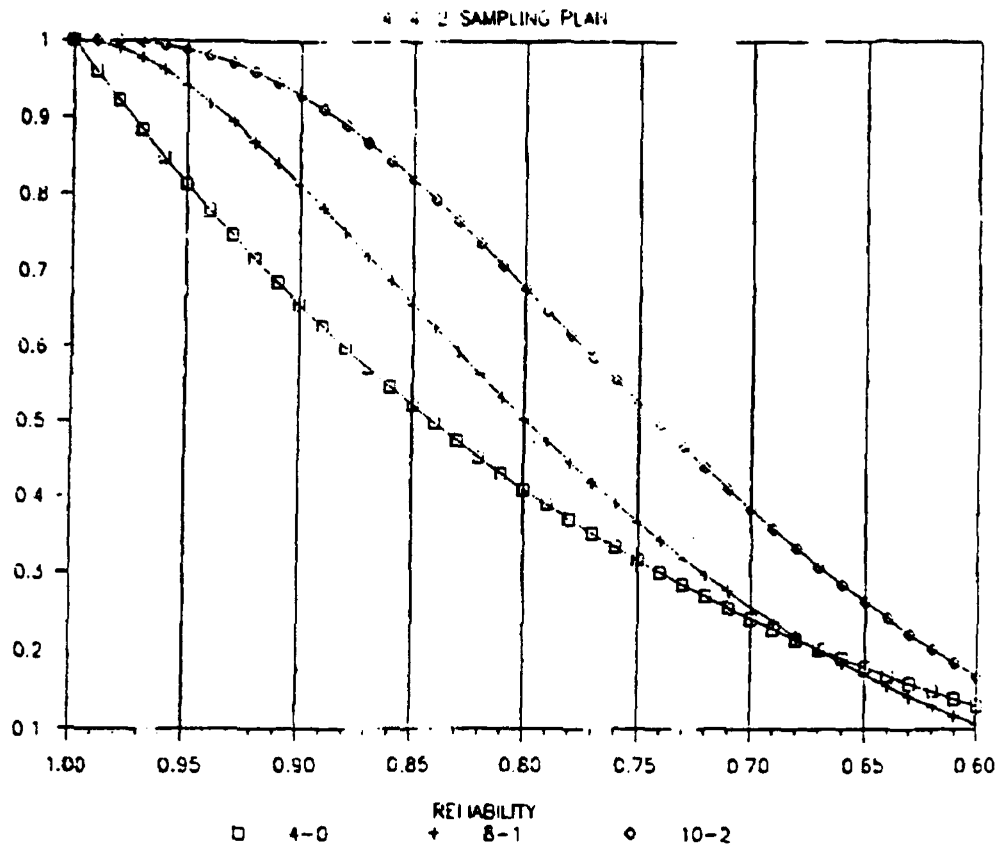

Figure 9 HELLFIRE OC Curve

Since the prohibitive cost involved in conducting this type of testing makes it unsuitable, it is safe to assume that except for the AQL, no other factors are pertinent to the overall QALVT issue.

2. The Longbow HELLFIRE QALVT Plan.

The Longbow HELLFIRE QALVT Plan, for reasons similar to the those for the HELLFIRE FTB and the desire to take advantage of HWIL ability to exercise the missile under all six of the scenario conditions, has a 6-6-3 multi-stage plan. This plan has the proviso that each missile will be run through each test scenario three times and that each missile is required to pass at least two of the three scenario trials in order to pass any given scenario. Failure is still determined by whether or not each missile successfully passed all six scenarios and whether or not the overall sample successfully passed the acceptance test. This statement also holds true regardless of where the acceptance determination is made, either during the first, second or third stages of testing. The specific characterisitics of the 6-6-3 plan and the resulting OC curve, by stage, can be seen in Figure 10.

The other major features of the HWIL QALVT Plan, that need to be discussed are the scenarios themselves. Because all of the Longbow HELLFIRE missiles must be run through each of the six scenarios, one might be concerned that one particular scenario might be more difficult than the others to

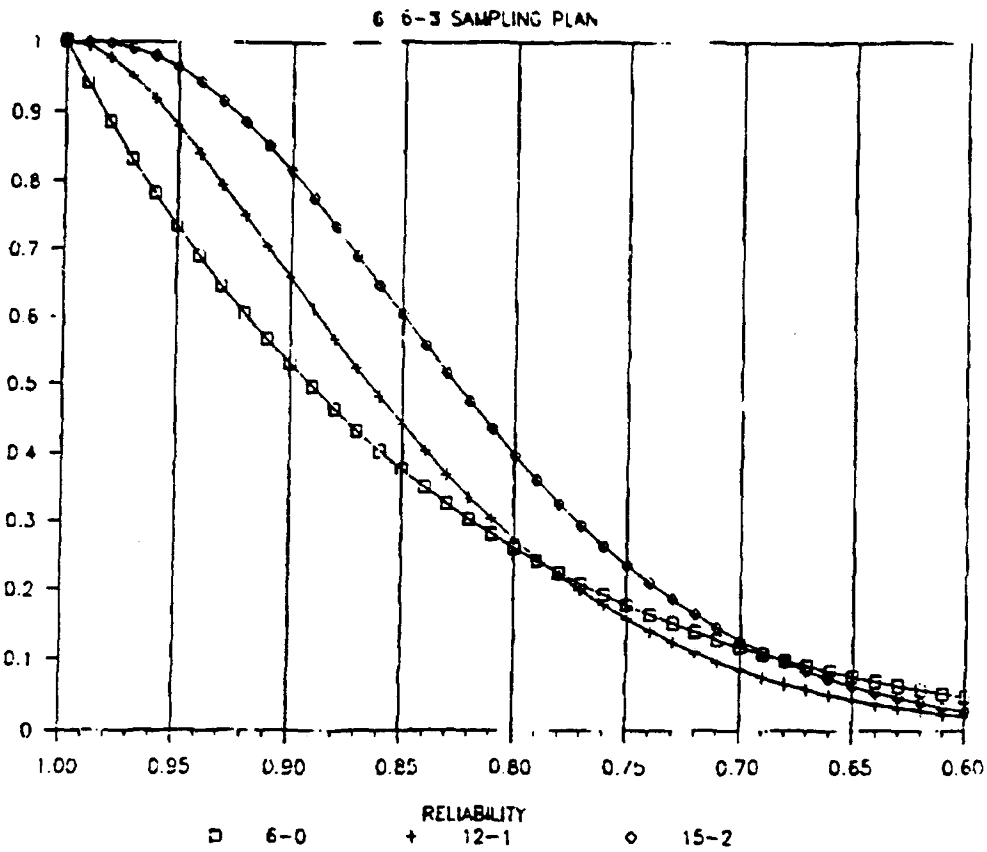

Figure 10 Longbow HELLFIRE HWIL OC Curve

pass. If this were true, than the acceptability of the entire lot might often be based on whether or not this scenario could be passed by the required number of missiles. To better understand this issue MICOM conducted a simulation study to determine to what extent each scenario was more difficult than another. The results of this simulation are depicted below in Table 5-1, Closed Loop Electronic Tests.

TABLE 5-1, CLOSED LOOP ELECTRONIC SIMULATION TESTS

Scenario	Results*
#1	+1
#2	(-19)
#3	0
#4	0
#5	(-21)
#6	+9

* Results are given in millimeters.

Each scenario was conducted 100 times and the Results column in the table displays the difference in millimeters between each scenario and scenario #3. The results are given in Circular Error Probability (CEP). Since the intended target of the Longbow HELLFIRE missile is a tank roughly 2 meters wide by 7 meters long by 2 meters high, the maximum deviations indicated in this table between each scenaıio is not very significant.

3. **Comparison.**

When comparing the two plans it appears that the HWIL QALVT Plan places the contractor at greater risk then the original FTB. This comparison is given in Table 5-2.

TABLE 5-2, COMPARISON OF PROBABILITY OF ACCEPTANCE.

	4-4-2 FTB Plan	6-6-3 HWIL Plan
STAGE #1	0.78	0.70
STAGE #2	0.92	0.84
STAGE #3	0.98	0.94
OVERALL TOTAL:	0.97	0.92

The information depicted in Table 5-2 was based on the assumption that the missiles being tested in either of the plans, do in fact, meet the contract system reliability requirement of 0.94[9].

In fact, the contractor has noted this increased risk and has contacted the Longbow HELLFIRE Program Office to register his concern. He has stated that he is being placed at greater risk than his previous exposure under former HELLFIRE contracts utilizing FTB. The PMO's response has been to take the issue under consideration until such time as the entire HWIL simulation plan solidifies to a point where a better determination on this issue can be made. Both plans

[9] Dick, R., "Binomial Sampling Plans Compaison", Brief, January 1990.

satisfy a requirement to accept the lot with probability greater then 0.92 when actual missile reliability is 0.94. Except for the testing cost factor ratio of approximately 7:1 in favor of HWIL, both plans would be acceptable for Government use.

The only other major area of comparison is the quantity of the sample size. In both cases the quantity used, was driven by the desire to make a determination of lot acceptability after the least amount testing and with the fewest number of missile test articles involved. The structure of each plan is basically the same except for the additional requirement, under the HWIL QALVT, that each missile must complete two out of three runs successfully for all six scenarios. This reason might give the impression of a significant difference. However, the likelihood of a missile passing one of the six scenarios, given it has passed one or more of the other scenarios is larger than it would be if this information were not available. That is, the outcomes of the scenario's tests are not statistically independent. In addition, the repeated three trials for each component are not statistically independent because it is the same missile under test in all three trials. This is based on the premise that HWIL testing involves testing only the electronic hardware of the guidance and control systems and the system software that run these components. It stands to reason that if these two components perform reliably the first time, they are more than likely to continue to perform appropriately for all the remaining trials within that scenario.

Thus, the trials and scenarios are not truly independent of one another as is assumed in the plan. This independence feature was used to compute the acceptance probability of 92%. If this f dependence is accounted for in a fairly conservative manner, the true acceptance probability is closer to 94%. While this number is closer to the FTB number, it may still represent additional risk to the contractor. The extent of this additional risk cannot be assessed without actual test data.

The real issue here is not the number of scenarios, number of trials, or pass/fail criteria, but the structure of the test in general. Many different test structures can be designed and their probability of lot acceptance computed as can be seen in Table 5-3 Sampling Plan Comparison.

However, what comes to light in the analysis of these test sampling plan schemes, is that they all are based on the assumption of multi-stage lot acceptance criteria, which assumes that there is a underlying desire to make a determination after the least amount of testing, because of the high cost that would normally be involved if this were true. This is not the case for HWIL simulation tests. As described earlier in Chapter II, the STAF facility can test about 20+ missiles a month at the same cost to do the 15 missiles in the plan.

TABLE 5-3, SAMPLING PLAN COMPARISON.

Sampling Plan (N - Acc - Rej)	Overall Probability of Acceptance given a Reliability of 0.94
20 - 2 - 3	0.885
10 - 1 - 2	0.882
9 - 0 - 2 9 - 1 - 2	0.762
8 - 0 - 2 8 - 1 - 2	0.799
7 - 0 - 2 7 - 1 - 2	0.836
6 - 0 - 2 6 - 1 - 2	0.872
** 6 - 0 - 2 ** 6 - 1 - 3 6 - 2 - 3	0.92 (0.937)
7 - 0 - 2 7 - 1 - 3 7 - 2 - 3	0.891
8 - 0 - 2 8 - 1 - 3 8 - 2 - 3	0.858
Fly To Buy	
4 - 0 - 2 4 - 1 - 3 2 - 2 - 3	0.971

Note: The ** 6 - 0 - 2 ** indicating the current test scheme. The 6-6-3 multi-stage HWIL plan still requires all 15 missiles to be delivered to the Government since there is no way of determining before hand, at what stage the decision will be made.

C. FLIGHT TESTING.

1. Introduction.

Flight testing beyond EMD and LRIP for the Longbow HELLFIRE missile will consist of firing 4 production missiles from static launchers, at Eglin AFB, Fl. One missile will be chosen from each batch of lot samples for each quarter year. These missiles will have already passed their particular lot acceptance test in the STAF facility prior to there selection for firing. Once selected they will be transported to EAFB and prepared for firing against one of the six scenarios used in the lot acceptance plan. This flight testing is expected to provide a quality check on areas of the missile system not tested under either of the earlier open and closed looped testing performed at RSA. These areas will include:

1) Rocket Motor and ignition device.
2) Electronic Safe and Arm device (ESAF).
3) Warheads and detonation train.
4) The Missile on board batteries.
5) Other Flight related Components not tested via HWIL testing.

Flight testing will also serve as a quality check and source of additional information on the HWIL Simulation process since all flight test missiles will be drawn from HWIL specimens. However, other than verifying that a test missile hits or misses the intended target, there is little means of effectively gathering useable data from these flight test missiles. None of these missiles will be electronically instrumented or outfitted with telemetry devices that could transmit guidance, trajectory, and flight data back to a ground station for post flight analysis. The only data gathering mechanism is the high speed filming from range tracking devices and the point of impact.

While the need for this testing is not being questioned, some very real and important questions do exist that could potentially adversely effect the HWIL lot acceptance process.

2. Question Areas.

a. Flight Test Significant.

As mentioned above, one missile a quarter will be test flown at EAFB. At this time there is no particular plan/guideline to cover or evaluate these flight test missiles. The sole evaluation criterion will be whether the missile hits or misses the intended target. Because these missiles are drawn from samples that have already passed the HWIL simulation, any failures during these flight tests will generate a series of unanswerable questions that will be difficult or impossible to resolve. Such questions as:

1) What specifically went wrong with the missile?

2) Should it have passed the HWIL Simulation and then

failed to hit the actual target; i.e., is there a potential defect in the simulation testing?

3) What do these flight test results indicate about the rest of the missiles in this particular production lot?

4) What needs to be fixed and how?

The first of these questions "What specifically went wrong?", may never be answered. Since there is no instrumentation, only obvious failures such as the rocket motor not igniting or the warhead failing to detonate could be investigated with any certainty. Less obvious problems involved in target misses may never be resolved.

"Should it have passed the HWIL simulation and then missed the target?". Because post flight data are limited, this question may never be answered satisfactorily. In fact, this particular question will likely serve to generate additional speculation in other areas such as transportation and mishandling.

The third question presents quite a major dilemma, because the minimum number of missiles necessary to answer this question is the same quantity that is indicated in the former FTB plan; namely four missiles per lot. Since there will be only one missile fired from one of the three lots accepted during that period, no meaningful inference can be made about other missiles in the lot using the one flight test.

Finally, the last question on the list represents the fall out from the other three. This question can only be answered after decisions are made relating to the other three questions. However, if some prior thought is not given to these questions before hand and a course of action taken, then this area will have to be dealt with after the fact when it will be potentially more difficult and costly to resolve.

b. HWIL Feedback.

It is understood that prior to any actual lot acceptance testing being conducted in the STAF facility, the process used by this facility will have to be validated to a certain level. Once that level is achieved, it will become difficult to improve on the process, because the source of data necessary to accomplish this activity; namely, telemetry instrumented test missiles will no longer be available. It stands to reason that the more information one has concerning a population of missiles (data base) the greater fidelity the modeling and simulation of that missile will be. The same holds true here. But as of now, there are no plans to build additional telemetry rounds, since these missiles are configured with a telemetry package in place of a warhead.

Any retro-fitting of production missiles is not desirable from two perspectives, 1) it will not be truly representative of the rest of the lot it was produced from, once retro-fitted, and 2) the cost involved makes it impractical.

Another alternative available to the Government to improve the HWIL simulation process, would be to allow the firing of several of the missiles that have been determined to be not acceptable by the closed loop test only. They could be taken to the flight test range and fired for the purpose of gathering additional information and insight into the process itself. Such a program would help to verify the accuracy of the simulation. This testing program may not be advisable for safety reasons, but the ability to confirm the good as well as the bad missiles would be a valuable feedback tool to improve the process as a whole.

D. VALIDATION AND CERTIFICATION

1. Background and Requirements.

HWIL simulations have been used on several occasions to help make lot acceptance determinations. Such systems as the Army's TACMS and Pershing missiles, and the Navy's Tomahawk Land Attack Missile (TLAM) have all used HWIL simulations in some form, but not as the basis for a lot acceptance process. In each case the validation of these simulations poses an all together different problem for each system for different reasons. Validation is concerned with the fidelity of the model and its accurate portrayal of the real life event. The procedures required to accomplish this validation are not always the same because system characteristics and requirements differ so radically from one to another. The validation process must be attacked on a case by case basis tailored for the unique characteristics of the system and the end product.

As of now, there is no set plan to accomplish this task, but several factors will be key to its successful completion. They are 1) the determination of the accuracy of the simulation to its real life counterpart, 2) the inherent reliability of the simulation to function properly and accurately portray the proper environment without inducing additional errors due to defects, anomalies or modeling errors into the process. In both of these cases, any factor that would decrement the outcome of this process from the real life environment that the missile would be subjected too, could be perceived by the contractor as additional risk to him and be a basis for an increase in costs and missile price. For example, suppose the simulation's accuracy was determined to be 95% faithful to the actual system's characteristics. What does this 5% difference represent to the two parties involved? Will it impact on the determination of the acceptability of the lots under inspection? 2) If the simulation software were deemed to work properly and produce an accurate result 99% of the time, the 1% of the time that it did not function properly could be perceived by the contractor as an additional 1% of risk he was assuming to perform lot acceptance. This would represent 1% more lots that might not be accepted by the

Government costing him additional rework and handling that may not be justified. Of course, the opposite case is also possible. The HWIL simulation process might be passing defective missiles.

No verification plan has been formulated or drafted to date, but several of these problems have been recognized by the facility developers. The mechanism requiring each sample missile to pass only two of three runs of each scenario is an example of an attempt to reduce the prospect of a simulation induced error effecting the overall acceptance of any particular lot.

These examples indicate an area of the Longbow HELLFIRE QALVT plan that has not been fully covered. One area that deserves additional attention pertains to what will happen when a HWIL simulation problem occurs during the pursuit of lot acceptance testing. Potential concerns in this area would center around the necessity of restarting that lot's testing, because it may not be determined if the problem detected in the missile under test went undetected in all prior missiles. If so, this would tend to invalidate prior testing on missiles for that lot. This would likely require retesting.

2. A Possible Validation Model.

As mentioned above, no specific lot acceptance simulation has been through the validation process to date.

However, there have been simulations that have been validated and certified for purposes very close to that which would serve the Longbow HELLFIRE system very well as a possible model for their certification program.

This system is the Navy's Tomahawk Land Attack Missile (TLAM), which used a computer simulation called the Interpretive Simulation Program No. 13 (ISP 13.0).

The ISP 13.0 simulates the TLAM and the environment in which it operates. It focuses on Block III and Pre-Block III Operational Flight Software (OFS) execution from power-up to missile impact.

The plan that the Naval Air Warfare Center, Weapons Division (NAWCWPNS) used to certify their simulation involved a concept by which they performed a comparison of ISP against accepted standards outlined in the Simulation Management Plan, Cruise Missile Project Office, July 1988. The certification includes validation data and verification data. The comparisons of simulation data with flight data comprised validation. The comparison of simulation data with previously certified simulation data (from earlier ISP versions 10.0, 11.0, & 12.03) comprised verification. In the case of ISP 13.0 the validation is performed by comparing its data with selected test flight telemetry data, and verification is performed by comparing against MVS-RLS[10] data. The

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[10] ISP-11.0 was updated/certified under a new name, MVS (RLS-1.1), in December 1991.

Certification Test Matrix described in TABLE 5-4 was used to perform this function and included all the runs for which ISP 13.0 has been subjected to during certification testing.

TABLE 5-4, ISP CERTIFACATION TEST MATRIX.

MISSILE	FLIGHT	OFS	PLATFORM	REMARKS
109C	OTL-39	BDV014	SUB-TTL	*
109C	OTL-78	LDV207	SUB-CLS	*
109A	OTL-45	BNV153	SHIP-VLS	*
109D	DT-3	BDV012	SHIP-ABL	*
109C	OTL-38	BDV014	SHIP-ABL	*
109A	OTL-32	BNV152	SUB-TTL	*
109C	OTL-40	BDV014	SUB-TTL	*
109C	TBAR-1	LDV400	SUB-CLS	**
109C	TBAR-2	LDV400	SHIP-ABL	**
109C	TBAR-3	LDV400	SHIP-ABL	**
109D	TBAR-4	LDV400	SHIP-ABL	**
109C	TBAR-7	LDV400	SHIP-VLS	**
109D	TBAR-8	LDV400	SHIP-VLS	**
109C	DT-1	LDV400	SUB-TTL	**
109C	DT-1R	LDV400	SHIP-ABL	***
109D	DT-2	LDV401.1	SHIP-ABL	***
109C	DT/OT-1	LDV401.1	SUB-TTL	***

Notes: * ISP-10.0 validation runs, resulted in provisional certification for BLK III ISP development.

** ISP-11.0 verification test runs, resulted in provisional certification for BLK III test flights.

*** ISP 13.0 validation and verification runs, to be completed for full certification.

The following parameters were plotted for ISP 13.0 runs from the test matrix above and compared with flight telemetry data for validation, and MVS (RLS-1.1) simulation for verification. The parameters were:

- Latitude versus Longitude.
- Inertial Altitude versus time.
- Roll versus time.
- Yaw versus time.
- Roll rate versus time.
- Pitch rate versus time.
- Yaw rate versus time.
- Mach command versus time.
- Mach versus time.
- North velocity versus time.
- East velocity versus time.
- Vertical velocity versus time.
- Normal acceleration versus time.
- TOA error versus time.
- Air temperature versus time.
- Static pressure versus time.
- Dynamic pressure versus time.

A typical plot that was developed to perform the comparison function for the DT1R: ISP 13.0...Inertial Altitude, Vertical Velocity, and Normal Acceleration vs Telemetry can be seen in the right hand column at Figure 11. The solid line in these graphs represents the simulation results. The dotted lines are the actual missile telemetry

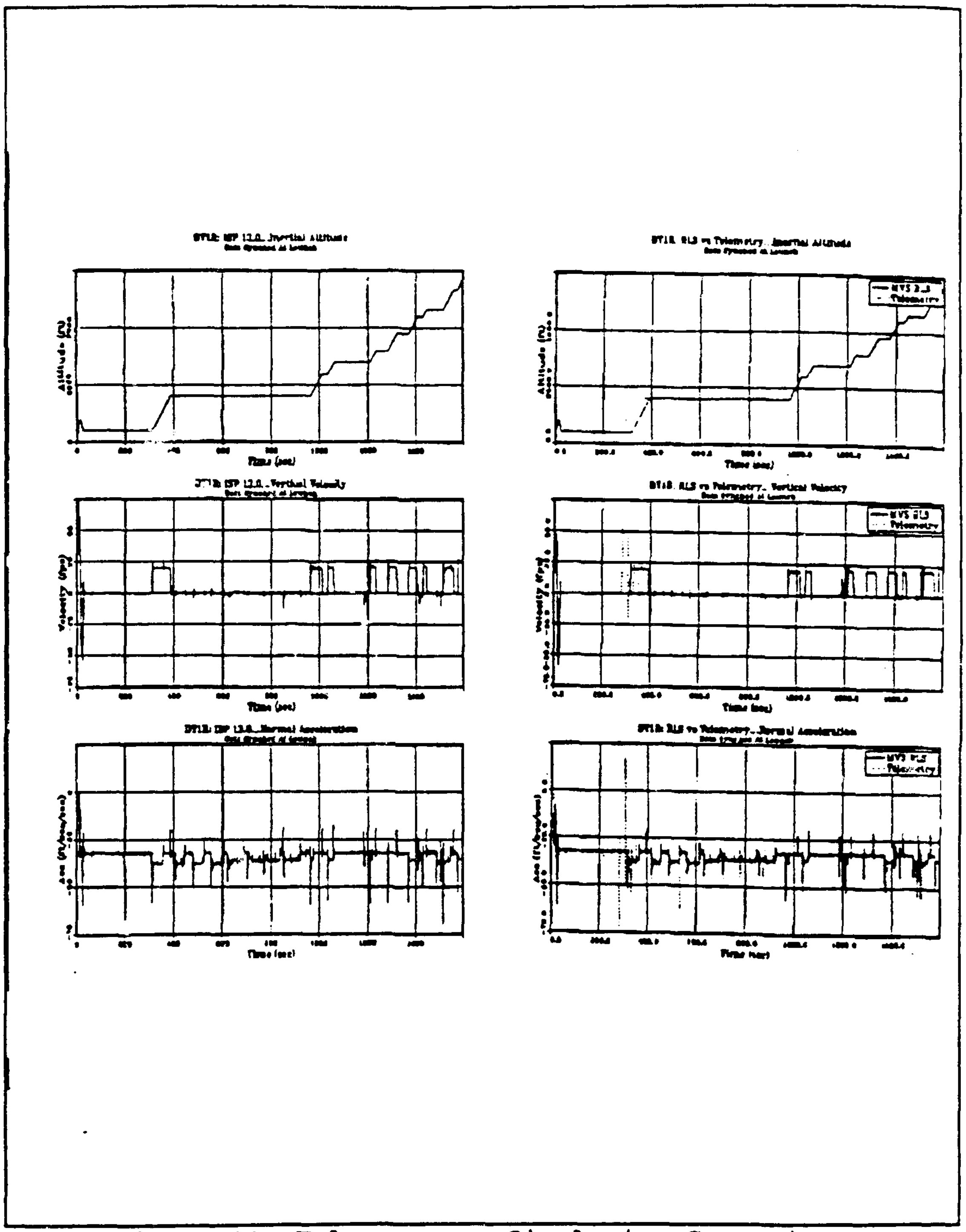


Figure 11 Telemetry vs Simulation Comparison

readings overlaid on the computer simulation graph. Figure 11 also depicts an example of the type of close match the Simulation Management Board would be looking for during the validation and certification process. A perfect match would be both graphs laid one upon the other.

The closer the simulation results (dotted lines) match the missile telemetry data (solid lines) the more accurate the simulation would be to the true life event it was modeling. If this were true for the majority of the parameters being modeled, and the results were consistent over a number of runs (simulation matched with flight telemetry data), then it could be reasonably assumed that the model was an accurate portrayal of these events. This is the approach that the TLAM Program Office is pursuing for their ISP model for the TLAM.

While the missile system attributes may be different for Longbow HELLFIRE system, the basic procedure to perform the certification process would be the same. This process is one of matching a number of simulation runs with their corresponding flight telemetry data, and then assessing the results between these two runs.

As with the TLAM Program, an independent Software Management Board (SMB) could be established to review the data and determine whether a certification of the simulation could be rendered.

To implement and control this task, a weapon specific simulation certification plan and process would have to be developed. An example of the process that TLAM used in their certification effort can be seen in Appendix C. This process could easily serve as a guideline for Longbow HELLFIRE's certification effort with some modifications.

3. Summary.

Validation and Certification of the HWIL simulation represents a significant challenge, but one that can be solved. The TLAM example is just one possible solution to this challenge. Further insight into this area can be obtained through a new book on the process of validating simulations entitled: "Simulation Validation, A Confidence Assessment Methodology". This book provides a generic foundations for describing, assessing, and structuring the simulation validation process and many of the problems areas that may be encountered along the way[11].

[11] Knepell, P.L., Simulation Validation, IEEE Computer Society Press, Los Alimitos, California, 1993.

VI CONCLUSION

A. INTRODUCTION.

After analyzing all the pertinent information and data regarding the Longbow HELLFIRE HWIL lot acceptances plan, several areas have been identified that may require additional attention prior to implementation of this test plan. These areas will form the basis of this chapter and will be discussed individually in order of importance.

B. BASIS.

In comming to a conclusion several areas stood out as being of particular importance to implementing the final HWIL acceptance plan. These areas are:

1) The role of Longbow HELLFIRE missile flight testing, as it pertains to HWIL lot acceptance testing.

2) The nature and extent of the validation and certification of the HWIL simulation.

3) How improvements in the process will be achieved.

4) Implications and future use by other systems.

5) Stockpile Surveillance.

1. The Role of Flight Testing.

The role of Longbow HELLFIRE missile flight testing presents one of the biggest potential dangers to the program if not addressed satisfactorily. Here you have a case where an insufficient quantity of missiles that will have all passed the HWIL simulation test are taken to the range and fired at a given scenario target with no attempt at either separating the results from the simulation or qualifying them with respect to the simulation. In both cases, given the small quantity (one missile flight per quarter) it will be extremely difficult to draw any kind of meaningful conclusion if a missile should fail to hit its target. Increasing the number of flight tests per quarter for the first fiscal year should facilitate the validation of the HWIL simulation. Failure analysis would be limited to trajectory and film reviews of the flight, and the specter of whether or not the simulation was passing on defective missiles could not be easily answered. The intended role of these flights was to prove out that non-tested areas of the missile such as the warhead and rocket motor will and do in fact function properly. The probability of detecting faults in these non-tested areas is not very large even when they occur in a significant proportion (say 15%) of the population of missiles if only four missiles are sampled per year. The probability, P_d, of detecting such a fault (if at least one of 4 missile fail) when 15% of the missiles are defective is:

$$P_d = 1 - (0.85)^4 = 0.478$$

The number of tests, n, needed per year to assure that the estimate, R, of the true successful flight reliability R is within one-fourth of a standard deviation of R with probability 0.90 is approximated by:

$$n = (1.645)^2 * 4^2 = 43$$

To be within one-half standard deviation of R with probability 0.90 requires about 10 missiles per year. If R = 0.85, the standard deviation is (0.85)*(0.15) = 0.1275. To be within one-fourth a standard deviation equates to R differing from 0.85 by + or - 0.03, with probability 0.90. To be within one-half a standard deviation equates to R differing from 0.85 by + or - 0.06, with probability 0.90.

2. Validation and Certification.

Validation and certification should be concerned with what can be reasonably tested and substantiated within the HWIL simulation test and what cannot. Knowing these limits and limitations will help determine what modifications to the entire procedure are warranted. As described earlier in Chapter V, there are existing programs that have successfully validated and certified their simulations. The TLAM example is just one method that has been performed that fulfills this requirement, and could be used as a model for the Longbow HELLFIRE validation and certification process.

3. Improvements.

It stands to reason that this is only the first step in what will be an eventual dependence on HWIL simulations for lot acceptance. Most improvements to the process will only be discovered after the facility is operational and certain amount of experience has been gained. With this in mind, some attention should be given to the area of planning for process improvements now to more easily take advantage of better methods as they become available.

4. Future System Application.

Other Army programs have been approached about using the STAF facility on a time sharing basis and using HWIL simulation to reduce testing costs. This program would include Non-Line of Sight (NLOS), the earlier HELLFIRE II, JAVELIN man-portable anti-tank missile, Brilliant Anti-tank (BAT), and CORPS SAM. The key factor here is the need to highlight the necessity of early planning to accomplish this task.

Longbow HELLFIRE has already demonstrated that it is much easier to design features into the missile that lend themselves to aiding the ease of HWIL testing, than attempting to correct these after the missile design has been locked in. In the case of Longbow HELLFIRE, the move to HWIL simulation meant determining an after the fact means to attach the simulation hook up cable through a sealed access panel in the missile body. In addition numerous signal and interface problems and modifications were needed. These requirements would have been easier to resolve if they had been included in the original system design to accommodate an HWIL approach.

Future systems should investigate this area during the design phase, so that HWIL critical features can be incorporated into the design.

5. Stockpile Surveillance.

Although, not a part of the Longbow HELLFIRE QALVT program, an area that warrants attention here because of its obvious impact, is stockpile surveillance. Normally at a predetermined time in the storage life of missiles, a certain quantity of missiles are selected at random from a given lot, inspected and test fired. This process helps assess deterioration characteristics of stored missiles and facilitate the identification of problems that can be corrected before they continue to degrade the rest of the stockpile. HWIL simulations may be useful for this type of testing and may provide substantial savings for the Government. In addition, some failures could in all likelihood be traced to a specific component and corrected; whereas with flight testing, the cause of the failure might never be determined. With failure modes identified, it would be that much easier to implement corrective fixes or incorporate them in future lots or designs.

VII AREAS OF CONCERN

A. GENERAL.

The purpose of this chapter is to identify potential problem areas that have so far come to light in this thesis. It is hoped that these suggestions are viewed as an aid to solving these problems and not as unsolicited criticism to a process that is already well along its way to providing substantial benefits for the Army and DOD.

B. THE PROBLEMS AREAS.

1. Flight Testing.

Flight testing, as it is currently planned in the Longbow HELLFIRE program, does not appear to provide significant added value to the QALVT program. The original purpose of this testing was to provide a basis to checkout other component areas of the Longbow HELLFIRE missile system that were not tested during the HWIL simulation process. However it suffers from certain major deficiencies that will hamper obtaining any meaningful results. Because only one missile out of a possible 250-400 missiles produced during a quarter will be fired, it will be extremely hard to draw any solid conclusions from any failures that may occur during these test flights. Since these test articles will be missiles accepted straight out of the STAF testing facility, failures after passing in those tested areas will be hard to explain if not attributed directly to some shortcoming in the HWIL simulation test itself.

There are no easy answers to this problem. Flight testing is absolutely essential to the process of determining whether the warhead, rocket motor, safe and arming functions, as well as the functions that were tested via HWIL are functioning properly under actual operational conditions. The crux of this issue is how to relate these tests to the simulation in a meaningful manner.

2. Feedback.

The HWIL simulation was developed and constructed with the aide of an extensive amount of actual fight test data and simulation work within the MICOM Laboratories. Because of this effort the people involved were able to develop this process to the point that it can be used for lot acceptance testing. This effort has been done largely in parallel with the current Longbow HELLFIRE EMD program. It has taken advantage of the numerous instrumented missile flight tests to perfect the HWIL simulation process. But now as EMD ends and production begins, access to additional sources of future flight data will not be available for process improvement. As discussed earlier only production configured missiles will be flight tested in the future. This will not provide any substantial feedback into the HWIL simulation process so that it can be further refined and improved.

3. Utilization By Future Systems.

As described earlier, a whole generation of future tactical and operational level missile systems could all benefit from this type of lot acceptance testing. The majority of these missiles already surpass the MICOM QALVT criteria or are very close to it. The major concern here is that these systems need to make decisions about simulation testing now while still in their developmental stages. It has already been discovered that as these systems increase in complexity the need to design in access and compatibility with simulation testing up front is crucial. Delaying this activity will only create additional design, interface, and cost problems.

While this is not a Longbow HELLFIRE specific problem, the people matrix from the Product Assurance Directorate to the program office should help disseminate this information to the rest of the community at large so that these insights can be incorporated into the next generation of missile systems. Lot acceptance planning, methods, processes, and procedures need to be identified and planned for in the early stages of development.

APPENDIX A LONGBOW HELLFIRE PROGRAM INFORMATION

DEVELOPER:	PEO Tactical Missiles; Project Manager, Air-to-Ground Missile Support Project Office, ATTN: SFAE-MSL-HD, Redstone Arsenal, AL. 35898-5610
PHONE:	(205) 876-8367
CONTRACTOR(S):	Martin Marietta, Rockwell International, and Westinghouse.
CONCEPT:	Longbow is a MMW fire-and-forget Hellfire missile system. It has an improved range over the standard Hellfire, and adds the capability for all weather operations.
TECHNOLOGY:	MMW fire control radar and seeker.
LETHAL MECHANISM:	Shaped charge warhead.
PRIMARY TARGET:	Armored vehicles.
PERFORMANCE:	Classified
STATUS:	Currently in the Engineering and Manufacturing Development (EMD) phase.
FUNDING:	
TIMETABLE:	Production should begin in late FY94.
SOURCE SUPPORT:	Project Manager, Air-to-Ground Missile

APPENDIX B STAF TEST FACILITY CAPABILITIES

OPEN LOOP TESTS

TRANSMIT/RECEIVE CHARACTERISTICS

VERIFY ANTENNA PATTERNS
VERIFY SEEKER POLARIZATION
VERIFY TRANSMITTER PULSE SHAPE
VERIFY SEEKER POWER
VERIFY TRANSMITTER CENTER FREQUENCY
VERIFY TRANSMITTER PRF
VERIFY TRANSMITTER FREQUENCY STEPS
VERIFY TRANSMITTER BANDWIDTH
VERIFY CROSS-POLARIZATION ISOLATION

ANTENNA CHARACTERISTICS

VERIFY ANTENNA PATTERNS
VERIFY BEAM WIDTH
VERIFY CROSS-POLARIZATION ISOLATION

TRACKING CHARACTERISTICS

VERIFY RANGE DISCRIMINATES
VERIFY ANGLE DISCRIMINATES
VERIFY DOPPLER RESOLUTION
VERIFY RANGE RESOLUTION

INERTIAL/CONTROL CHARACTERISTICS

VERIFY FIN RESPONSE
VERIFY FIN FEEDBACK
VERIFY INERTIAL MEASUREMENT SENSOR

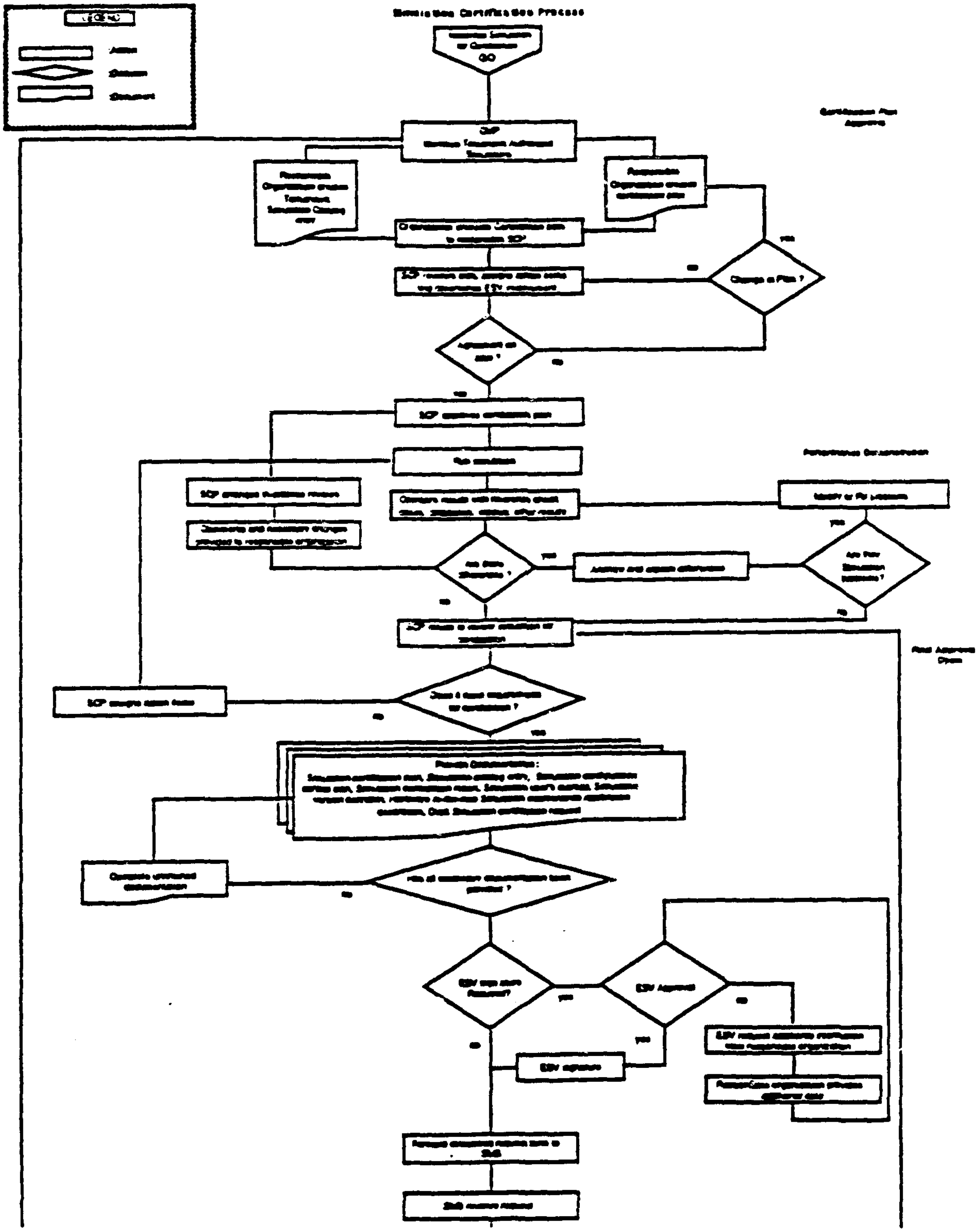
CLOSED LOOP TESTS

COMPLETE SYSTEM FUNCTIONALITY TESTS IN NONDESTRUCTIVE TACTICAL FLIGHT SCENARIO

INCLUDING:

ACTUAL TACTICAL LINE OF SIGHT RATES,
RANGE EXTENDED TARGETS,
TARGET DYNAMICS,
VARIOUS LAUNCH CONDITIONS AND GEOMETRIES

APPENDIX C TLAM SIMULATION CERTIFICATION PROCESS



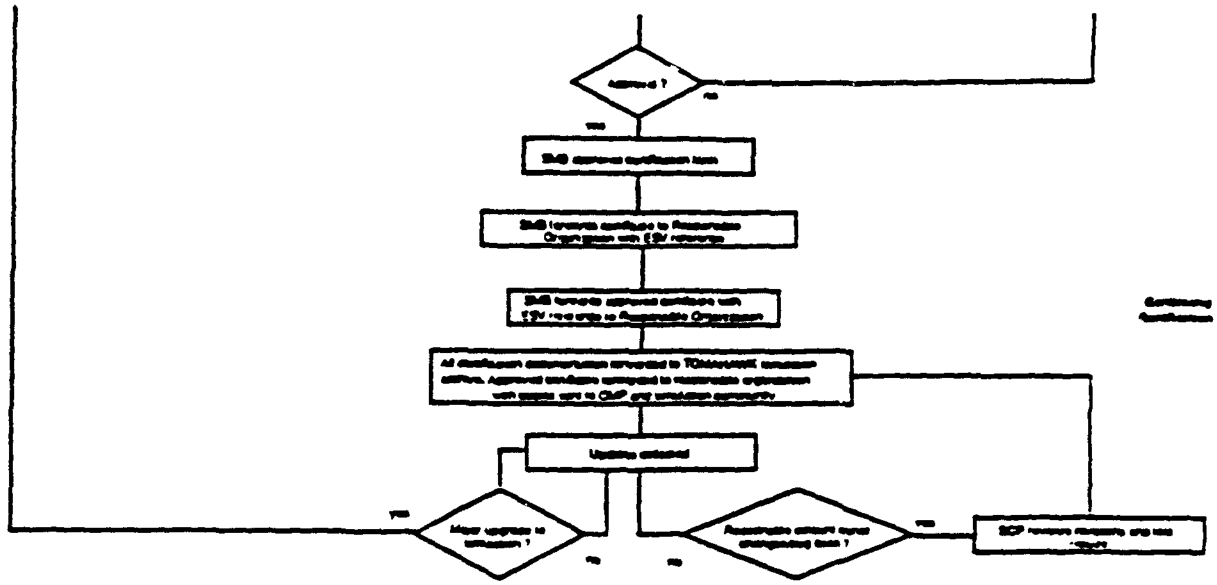


Figure 2 Certification Flow Chart for Effectiveness and Survivability Simulations

CERTIFICATION PLAN APPROVAL

Once a simulation has been authorized for Tomahawk effectiveness and survivability analyses the SMB tasks the TWS E&S SCP with scheduling the simulation for certification/accreditation. The first step in this process is the submission of a certification plan to the SCP for approval. The certification plan specifies what will be tested, how it will be tested, and what comparisons will be made to reference check cases and other data in the process of certification of a simulation. A basic set of reference check cases are detailed at the end of this appendix. These reference check cases allow the responsible organization a media for comparison to demonstrate that a simulation is certifiable. Comparison of simulation data to reference check case data should be included as the first step in any certification plan. The responsible organization may propose any cost effective combination of the below methodologies to complete certification. In order of decreasing priority:

1) Comparison to flight test data;
2) Comparison to other simulations whose certification basis is flight test comparison;
3) Comparison of data with other certified simulations;
4) Technical audit of simulation performance;
5) Demonstration of simulation capability.

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